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CORRELATIONS BETWEEN THE HYDRANTH COMPONENTS OF OBELIA COLONY POPULATIONS*

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(Received for publication April 11, 1946)

"We must reflect that where so much strength is spent in finding a way of telling the truth: the truth itself is bound to reach us in rather an exhausted and chaotic condition."
VIRGINIA WOOLF: MR. BENNETT AND MR. BROWN

INTRODUCTION

It is *a priori* apparent that an Obelia colony is a concinnate aggregate of inter-related hydranth structures. But science demands evidence. Quantitative as well as qualitative. Ample qualitative evidence is available.

The life-cycle progression of an Obelia hydranth is marked by a succession of definitive structural states, viz. buds: cones (halves): cylinders (three-quarters): complete organisms: senile animals: and empty hydrothecae. These, plus pedicels broken by injury are the hydranth components of Obelia colony populations (Hammett, 1933: 1943a).

Evidence of interdependence between these structures is the fact that all are served by the same streaming hydroplasm as it circulates throughout the colony. The hydroplasm which carries building-stuff to the growing parts: and dissolution-stuff away from the disintegrating (Hammett and Padis, 1935: Chapman, 1937: Hammett and Chapman, 1938).

Evidence of inter-relation between structures is the fact that each

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may be seen to evolve from its antecedent in the series: and to give rise to its succedent. Empties and brokens go on to buds: buds to halves: halves to three-quarters: three-quarters to completes: completes to seniles: seniles to empties: and some to brokens: in ever-recurring cycle. Thus is colony morphogenesis expressed (Hammett, 1943a).

And since each structure is the product of its immediately antecedent, and the producer of its immediately succedent structure: while these in turn are the products and producers of others in the cycle: the 7 indubitably constitute an inter-related aggregate of which colony population is the integrated expression.

Consistent is the coordination expressed in season change in colony composition with respect to buds and completes (Hammett and Hammett, 1945).

This is all very nice. But qualitative evidence is only a beginning. What is wanted is not only quantitative demonstration of inter-structure relationships; but also mathematical statements of their extent and nature.

With such the relations become concrete and workable for expanding knowledge. Concrete data are a necessary foundation of any mathematical formulation of growth and its sequalae. Of which colony composition is an expression.

Any equation of growth which is not grounded in the quantitative relations existing between *all* the basic expressions of the property is a futile gesture (Hammett, 1943a).

Mathematical statements of the correlation between the 7 hydranth structures comprising colony population may provide a partial foundation for such an equation.

For each structure is definitive of the coming into dominance of a basic growth or plasergic activity. Thus buds are a mark of initiation: halves of proliferation: three-quarters of differentiation: completes of organization and maintenance: seniles of catabolism and regression from maintenance: empties of catabolism: and brokens of injury and catabolism (Hammett, 1933: 1936: 1942a: 1942b). So this report presents and analyzes the quantitative relations between the 7 hydranth structures in Obelia colony populations.

Material and Procedure

The raw data are the numbers of hydranth buds, halves, three-quarters, completes, seniles, empties, and brokens in single sets of colonies assembled by single workers on single days. The same as those used in the study of season change in colony composition. Their source, collection, selection, and assembly are there described (Hammett and Hammett, 1945).

Some 3500 sets were recorded. Table 1 gives samples. It would be ruinously exhibitionistic to give all. But all are available.

Each set is a population sample compounded of 7 variables. For the table shows the buds, halves, etc. vary in number from population to population. Quantitative statement of relation between any 2 structures is gotten by comparing the numerical change in one with that of the other within an array of such populations, i.e. by comparing increase and decrease in buds with increase and decrease in halves, etc. In other words by getting the correlation in variation.

This may be done in several ways. But statisticians consider computation of the coefficient of correlation gives a most useful result. For—as Miner puts it (1922)—

"A coefficient of correlation measures the degree to which two variables are associated, taking the value +1 when a deviation of one variable from its mean is always associated with a proportional deviation of the other in the same direction, decreasing as the intensity of the association decreases until for complete independence of the two variables it takes the value 0, and again increasing in numerical value but with a negative sign for increasing intensity of association where deviations of one variable in one direction are coupled with deviations of the other variable in the opposite direction. Thus the absolute magnitude of a coefficient of correlation measures the intensity of the association of two variables, while its sign indicates whether as one variable changes the average values of the other variable change in the same or opposite direction. The possible range of values is from +1 to —1."

Thus 2 aspects of relation between any 2 structures, viz. direction and extent, are shown in the single value. When this is plus, the 2 are said to be positively correlated. And the association is conjunctive. When it is minus, the 2 are said to be negatively correlated. And the association is disjunctive. Differences in magnitude of co-

TABLE 1

THE NUMBERS OF BUDS, HALVES, THREE-QUARTERS, COMPLETES, SENILES, EMPTIES, AND BROKENS IN EACH OF THE 48 SETS OF VARIABLES AVAILABLE IN APRIL 1938

	Bd	½	¾	Co	Sn	Em	Br
	53	15	25	193	6	2	6
	41	11	25	175	8	0	9
	48	6	23	181	5	5	6
	54	6	17	165	3	1	1
3C	35	13	15	221	4	2	15
(12)	36	9	28	185	3	2	6
	31	12	20	187	6	2	13
	50	7	17	198	7	1	7
	50	8	23	213	5	1	7
	33	9	14	190	3	2	9
	43	9	19	186	6	2	5
	42	8	18	194	3	7	8
	53	10	24	195	4	4	12
	49	7	25	181	3	1	5
	42	9	28	179	9	2	4
	46	11	14	174	4	2	5
3T	35	10	27	214	1	2	17
(12)	39	9	15	194	4	2	9
	38	12	18	194	3	4	12
	40	7	19	210	6	1	7
	56	4	25	213	3	2	9
	47	8	23	190	3	0	7
	37	13	15	187	1	1	6
	46	5	19	210	3	3	5
	49	10	17	241	0	0	3
	27	5	19	187	2	1	8
	50	6	13	179	8	12	11
	34	7	11	220	0	5	5
4C	47	8	23	230	9	4	14
(12)	50	15	13	187	7	4	12
	32	9	18	188	3	2	9
	40	6	17	229	10	7	7
	61	10	33	252	2	2	4
	42	8	22	174	1	2	0
	43	16	14	177	2	6	5
	49	5	15	193	2	5	0
	46	8	18	242	1	0	1
	20	13	17	191	1	0	11
	38	10	27	183	7	6	7
	37	4	10	220	0	2	7
4T	50	6	18	231	11	5	15
(12)	53	11	15	184	10	5	6
	42	4	16	188	4	3	5
	42	5	19	234	5	8	5
	55	13	32	250	5	3	6
	41	13	19	168	2	3	6
	48	11	20	174	1	6	2
	46	7	13	198	0	3	1

efficients indicate differences in extent to which association is expressed between different couplings.

As will be seen, such data contribute to evaluation of colony composition, growth, and reaction to experiment. From which the more recent concept of growth (Hammett, 1936: 1942b) gains new substance. *Quien adelante no mira atras se queda.*

The "significance" of a correlation coefficient—or whether it truly shows association regardless of its magnitude—depends upon its error. This is factored by the number of variates. In the present case the variable number of each structure is the variate thereof. Thus the 53 buds in the 1st set of table 1 is one variate of the variable "bud"; the 43 buds of the 2nd set is another; and so on similarly. The number of variates of each variable available for computation is determined by the number of available sets. The table shows 48 such in April 1938.

With 4-place coefficients 50 variates is minimum. Special treatment is advocated for fewer (Pearl, 1940: Yule and Kendall, 1937). In most practical work 3-place coefficients are adequate. Here 30 variates suffice (Ezekiel, 1941). The population sets have therefore been segregated on a monthly basis. First because this gives the required number of variates (cf. table 5). Second because this would bring out any season differences which might be present.

Of the available sets, 3,462 were used. The others were rejected because of extreme variates. May 1933 is omitted because the number of hydranths and sets was inadequate for standard treatment. The number of months is therefore 36 instead of 37 as in the season study. The years of observation are of course 7.

No space is given to theory and practice since such is covered by Tippet (1931), Fisher (1936), Davenport and Ekas (1936), Pearl (1940) and Ezekiel (1941). Pearl; and Davenport and Ekas; give more suitable directions for the neophyte. But all deserve study. Our procedure for getting material into shape for analysis is as follows.

A set-by-set tabulation of the numbers of buds, halves, etc. in sets of colonies as collected is first drawn up as shown in table 1 for April 1938 data. This is the 1st work-sheet.

The variates of each variable are next tabulated in the order of ascending magnitude as in table 2. This is the 2nd work-sheet.

Using this, the distribution of each seriation is tested for extreme

TABLE 2

SERIATION OF THE VARIATES OF THE SEVEN VARIABLES OF TABLE 1

♯	Co	♯	Bd	♯	½	♯	¾	♯	Sn	♯	Em	♯	Br
	165	1	20		4		10		0		0		0
2	168	1	27	3	4	2	11	4	0		0		0
	174	1	31		4		*13		0	5	0	5	1
	174		32		5		13		0		0		1
5	174		33	4	5	2	13		1		0		1
	175	5	34		5		14		1		1		2
	177		35		5		14	6	1		1	2	3
	*179		35		*6		14		1		1		4
	179		36		6	8	15		1	7	1		4
	181		37	4	6		15		1		1		5
6	181	6	37		6		15		2		1		5
	183		38		6		15		2		1		5
	184		38		7		15	5	2		2	10	5
	185		39		7		16		2		2		5
	186		40	5	7		17		2		2		5
	187		40		7	6	17		3		2		5
	187		41		7		17		3		2		5
	187		41		8		17		3		2		6
10	187		42		8		17		3		2		6
	188	11	42	6	8		18	10	3	15	2		6
	188		42		8		18		3		2		6
	190		42		8		18		3		2		6
	190		42		8		18		3		2		6
	191		43		9		18		3		2	14	6
	193		43		9	11	19		3		2		7
	193		46	6	9		19		4		2		7

TABLE 2 (*continued*)

♯	Co	♯	Bd	♯	½	♯	¾	♯	Sn	♯	Em	♯	Br
	194		46		9		19		4		2		7
8	194	6	46		9		19	5	4		3		7
	194		46		9		19		4		3		7
	195		47		10		19		4	5	3		7
	198		47		10		20		5		3		7
	198		48	5	10	2	20	4	5		3		8
1	201		48		10		22		5		4		8
	210		49		10		23		5	4	4		9
3	213	9	49		11	5	23		6		4	7	9
	213		49	4	11		23	4	6		4		9
	214		*50		11		23		6		5		9
3	220		50		11		24		6		5		9
	220		50		12		25		7	5	5		*11
1	221		50	2	12	5	25	3	7		5	1	11
	229		50		13		25		7		5		12
4	230		53		13		25		*8		6	4	12
	231		53	5	13		27	1	8	3	6		12
	234	5	53		13	2	27		9		6		13
1	241		54		13		28	2	9		7		14
				0									
1	242		55		15	2	28		10	2	7	3	15
						0							
	250	1	56	2	15		32	2	10	1	8		15
2	252	1	61	1	16	2	33	1	11		**12	1	17
Class Range	*7*		*4*		*1*		*2*		*1*		*1*		*2*
No. Classes	*13*		*11*		*13*		*12*		*12*		*9*		*9*

variates by Chauvenet's procedure (Davenport and Ekas, 1936). The sample shows one such: in the "Empties" series. The variate "12" is too far above the upper legal limit of 9.2. So the 12 is not used. Nor are its companions in the set in which it occurs. So the set is deleted by encirclement in table 1. And in table 2 by starring the variates of the other variables in the set. This leaves 47 variates of each variable for use in computation. Minor deviations are not excluded.

The variates in table 2 are next segregated into classes. The aim is to have from 8 to 14: with inclination towards the higher. Thus a class range of 7 in the complete series gives 13 classes. And so on similarly.

The classes are set off and the number of variates in each recorded as shown. From these data the grilles for each pair of variables are constructed according to Pearl (1940). Using the number of classes, the class range, and the number of variates in each seriatim. Then the data of table 1 are entered in the proper grille: variable-to-variable and set-by-set. The serial record of variate number is checked on accuracy of the distribution. And the correlation coefficient is computed by Pearl's procedure: checked by that of Davenport and Ekas.

There are 36 months of record similar to that of April 1938. Or 36 population arrays. The coefficient of correlation of each 2 structures is computed for each array. This means 36 separate measures of the relation between any 2 structures are had. These are set down in table 3 for each coupling. The 7 structures yield 21 such couchants. So there are 21 sets of 36 coefficients in each; or a total of 756 coefficients.

Each of these Zero Order coefficients is measure of association of 2 structures when subject to the influence of variation in the other members of the family of structures. The intrinsic association, or that existing between 2 structures free from family interference is also wanted. An early experience with biometric analysis of organ weight inter-relations in the rat showed that such may be gotten by the method of partial correlation (Hammett, 1926*a* and *b*). The rationale and practice of this procedure are given by Pearl (1940) and others.

So the Zero Order coefficients were put through this mill. The

TABLE 3

ZERO ORDER CORRELATION COEFFICIENTS

Obelia Hydranth Buds, Halves, Three-Quarters, Completes, Seniles, Empties, and Brokens

	1933	1934	1935	1936	1937	1938	1939
			Completes: Buds				
April	—	—	—	—	—	+.201	—.425
May	—	+.590	*+.208*	—.301	+.473	+.184	+.095
June	+.466	+.267	+.060	—.086	+.032	—.293	—.534
July	+.281	+.076	—.028	—.111	—.346	*—.190*	+.265
Aug.	—.108	+.128	+.100	—.137	—.365	—.170	+.022
Sept.	+.089	+.292	*+.283*	+.025	—.618	*—.302*	*+.386*
			Completes: Halves				
April	—	—	—	—	—	—.177	—.229
May	—	+.764	+.285	—.053	+.494	+.038	*—.337*
June	*—.290*	+.171	+.154	+.047	+.271	—.020	—.060
July	+.138	*—.227*	+.060	—.119	—.418	—.376	—.427
Aug.	—.302	*—.202*	+.240	*+.183*	—.025	—.290	—.329
Sept.	—.077	—.170	+.176	+.119	—.193	—.055	—.160
			Completes: Three-Quarters				
April	—	—	—	—	—	+.152	—.032
May	—	+.577	+.352	+.079	*+.205*	+.093	—.066
June	—.203	+.330	+.152	—.018	—.357	—.120	—.370
July	+.187	+.129	—.262	*—.209*	—.515	—.318	—.331
Aug.	—.358	+.347	—.051	*—.186*	—.080	—.045	—.036
Sept.	—.007	+.335	—.086	—.140	—.381	—.103	+.176
			Completes: Seniles				
April	—	—	—	—	—	+.033	—.440
May	—	—.035	—.102	—.083	+.049	+.098	—.205
June	—.467	+.084	*—.200*	—.352	+.035	—.455	—.121
July	—.139	—.106	—.367	—.527	—.335	—.402	—.366
Aug.	+.115	—.084	—.071	—.296	—.442	—.580	+.088
Sept.	—.173	+.227	+.091	—.513	*—.272*	—.017	—.271
			Completes: Empties				
April	—	—	—	—	—	+.050	—.251
May	—	+.461	+.005	+.065	+.024	+.026	—.495
June	—.057	+.259	—.306	—.403	—.278	—.255	—.115
July	—.041	—.322	*—.181*	—.423	—.276	*—.227*	—.373
Aug.	—.111	—.235	—.159	*—.190*	—.456	—.379	+.053
Sept.	—.059	+.042	+.358	—.352	—.191	—.162	—.158
			Completes: Brokens				
April	—	—	—	—	—	+.149	—.446
May	—	+.232	—.113	+.158	—.011	—.016	—.251
June	—.115	+.106	—.641	—.260	—.259	—.063	+.299
July	—.099	—.341	—.231	—.330	—.011	—.312	—.380
Aug.	+.159	—.324	—.369	—.236	—.282	—.122	+.027
Sept.	—.380	—.031	+.049	*—.240*	+.143	—.125	*—.314*
			Buds: Halves				
April	—	—	—	—	—	—.087	+.271
May	—	*+.390*	*+.122*	+.428	+.342	—.007	—.234
June	+.043	+.263	—.023	+.250	+.155	—.078	+.011
July	+.104	+.300	+.163	*+.192*	+.161	—.034	—.277
Aug.	*+.211*	—.094	+.120	+.265	+.056	—.114	—.104
Sept.	+.142	—.011	+.303	*+.245*	+.001	—.126	—.049

TABLE 3 (*continued*)

	1933	1934	1935	1936	1937	1938	1939
			Buds: Three-Quarters				
April	—	—	—	—	—	+.*307*	+.028
May	—	+.049	+.134	—.033	+.*190*	+.364	+.145
June	+.051	+.165	+.449	+.436	+.*196*	—.115	+.290
July	+.118	+.*212*	+.*187*	+.*168*	+.*200*	—.060	—.030
Aug.	+.482	+.071	+.079	+.141	+.410	+.016	+.451
Sept.	+.*258*	+.245	+.432	—.*285*	+.280	+.019	+.182
			Buds: Seniles				
April	—	—	—	—	—	+.209	+.082
May	—	+.028	—.*244*	—.141	+.073	+.043	+.153
June	—.235	—.235	+.355	+.132	+.017	+.187	+.*229*
July	—.010	+.122	+.051	+.110	+.039	+.*229*	—.640
Aug.	—.059	+.263	+.*187*	—.072	—.025	+.077	+.013
Sept.	+.416	+.078	+.125	—.137	+.207	—.208	—.623
			Buds: Empties				
April	—	—	—	—	—	+.110	+.030
May	—	+.*364*	—.040	—.439	—.039	+.*222*	+.168
June	+.071	—.079	—.139	—.041	—.231	+.000	+.188
July	—.043	+.039	—.039	—.233	—.121	+.256	—.515
Aug.	+.051	—.008	+.024	—.269	—.015	—.260	—.*252*
Sept.	+.123	—.166	—.220	—.146	+.119	—.*249*	—.409
			Buds: Brokens				
April	—	—	—	—	—	—.*307*	+.*307*
May	—	—.099	—.421	—.408	—.230	—.102	—.*281*
June	—.360	—.053	+.037	—.422	—.138	—.403	—.321
July	+.096	—.*224*	—.349	—.541	—.352	+.000	—.463
Aug.	—.267	—.263	—.376	—.503	—.273	—.512	—.344
Sept.	—.554	—.684	—.*232*	—.317	—.397	—.201	—.697
			Halves: Three-Quarters				
April	—	—	—	—	—	+.091	—.*301*
May	—	+.*355*	+.087	+.171	—.106	—.097	—.093
June	+.050	+.122	—.094	+.138	—.112	—.*206*	—.156
July	+.*267*	+.180	+.236	+.039	+.024	—.038	+.*244*
Aug.	+.271	+.108	+.*200*	+.131	—.166	—.100	—.199
Sept.	+.099	+.152	+.065	+.219	—.205	—.185	—.249
			Halves: Seniles				
April	—	—	—	—	—	+.027	+.035
May	—	—.142	—.013	+.017	+.274	+.097	—.114
June	+.*263*	+.055	+.047	+.068	+.*181*	+.040	+.089
July	+.285	+.011	—.002	+.126	+.305	+.151	+.332
Aug.	+.*217*	—.099	—.057	—.144	+.069	+.*209*	+.046
Sept.	+.076	—.237	+.011	+.049	+.108	+.010	+.071
			Halves: Empties				
April	—	—	—	—	—	—.*062*	+.185
May	—	+.*349*	—.107	—.033	+.170	+.015	+.018
June	+.043	+.007	+.033	—.235	—.064	—.*208*	+.071
July	+.199	+.180	+.124	+.005	—.*213*	+.171	+.311
Aug.	+.188	+.064	+.021	—.001	—.*223*	+.*193*	—.*221*
Sept.	—.075	+.191	+.177	—.170	—.286	—.068	—.217

TABLE 3 (*continued*)

	1933	1934	1935	1936	1937	1938	1939
			Halves: Brokens				
April	—	—	—	—	—	+.277	+.157
May	—	+.228	−.080	−.235	+.207	+.208	−.001
June	+.037	−.094	+.044	−.289	−.224	+.022	−.183
July	+.235	−.033	−.308	−.112	−.088	+.219	+.115
Aug.	+.087	−.120	−.398	−.320	+.129	−.120	−.225
Sept.	−.195	−.272	−.161	−.129	+.113	−.065	−.147
			Three-Quarters: Seniles				
April	—	—	—	—	—	+.193	−.012
May	—	−.069	+.130	−.054	−.069	+.152	+.140
June	−.156	+.124	+.152	+.179	−.130	+.053	−.011
July	+.345	+.070	+.324	−.055	+.089	+.081	+.194
Aug.	−.111	+.377	−.013	+.060	−.106	−.138	−.062
Sept.	+.151	+.191	+.158	+.128	−.245	+.048	−.293
			Three-Quarters: Empties				
April	—	—	—	—	—	−.120	−.029
May	—	+.338	+.041	−.242	+.024	+.220	−.079
June	+.155	+.229	−.290	+.098	+.011	+.123	−.072
July	+.236	−.010	+.001	+.062	+.058	−.094	+.323
Aug.	+.201	−.063	−.053	+.095	−.092	−.039	+.030
Sept.	−.174	−.110	−.251	−.017	+.195	−.166	−.150
			Three-Quarters: Brokens				
April	—	—	—	—	—	+.102	−.394
May	—	+.276	−.212	−.084	−.403	−.101	+.005
June	+.020	+.053	−.163	−.096	−.128	+.073	−.146
July	+.096	−.321	−.351	−.101	−.133	+.042	+.115
Aug.	−.139	−.243	−.348	−.288	−.313	−.172	−.055
Sept.	−.366	−.333	−.330	−.133	−.267	−.324	−.365
			Seniles: Empties				
April	—	—	—	—	—	+.257	+.286
May	—	−.104	+.157	+.262	+.360	+.340	+.243
June	−.198	+.240	+.094	+.413	+.075	+.270	+.243
July	+.242	+.118	+.004	+.247	+.017	+.385	+.599
Aug.	+.167	+.115	−.114	+.028	+.327	+.369	+.231
Sept.	+.127	+.128	−.154	−.015	+.160	−.017	+.430
			Seniles: Brokens				
April	—	—	—	—	—	+.350	+.274
May	—	+.259	+.213	−.097	+.309	+.304	+.071
June	+.278	+.140	+.200	+.237	+.146	+.076	−.053
July	+.526	+.058	−.066	+.221	−.079	+.069	+.594
Aug.	+.101	+.063	−.071	+.094	+.354	+.143	+.207
Sept.	−.211	+.178	−.065	+.085	+.055	−.059	+.651
			Empties: Brokens				
April	—	—	—	—	—	+.040	+.233
May	—	+.196	+.009	+.305	+.135	+.103	+.232
June	+.124	+.222	+.304	+.564	+.215	+.245	+.161
July	+.353	+.284	+.099	+.471	+.188	+.111	+.587
Aug.	+.135	+.254	−.008	+.195	+.302	+.329	+.211
Sept.	+.111	+.221	+.276	+.413	+.011	+.186	+.419

results are given in table 4 as 5th Order coefficients. Each measures the intrinsic or *sui generis* association between the stated 2 structures.

The labor in getting such data is considerable. It took pairs of computers more than 5 years to calculate and check the necessary 17,712 coefficients. Time spent in computing significance is included: but time spent in organizing the data for analysis is not. One wonders if the results are commensurate with the expenditures.

Three tests are commonly used to estimate whether or not a coefficient indicates significant association between 2 variables. These are the Standard Error, the Probable Error, and the t value. Each has been computed. Record of Standard and Probable Errors is not given. Such would double space taken by tables. Instead the t value is used. First, because it seems to be preferred by Fisher (1936), Davenport and Ekas (1936), and Ezekiel (1941): and second, because with it a Standard Coefficient suitable for testing all the 21 correlations of a month's array may be computed. Which means that only 36 instead of 756 indices need be recorded; as would be required if Standard or Probable errors were given.

The formula for the Standard Coefficient is:

$$x/\sqrt{1-x^2} = t\sqrt{N-2}$$

where x is the Standard Coefficient (Sr): t is gotten for the number of variates from table XIII of Davenport and Ekas (1936); and N is the number of variates.

Using April 1938 (table 1) as example, N is 47: t is 2.6852: and Sr comes out as 0.372. So the coefficient of correlation of any 2 structures in this array must be no smaller if the association is to be considered significant. In other words, coefficients of 0.372 or over indicate unquestionable association on this basis. Coefficients smaller than 0.372 indicate uncertain or no association. Thus—the April 1938 Zero Order coefficient of buds and brokens is —0.307. Association here is to be questioned. The 5th Order value is —0.472. Here association is sure. And so on similarly.

The Sr values for each month's arrays are given in table 5. They are applicable to both the Zero and 5th Order coefficients since both derive from the same number of variates, and it is this which sets the value of t.

Since *PE*-valid coefficients are indicative of association trend, such

TABLE 4

5TH ORDER CORRELATION COEFFICIENTS

Obelia Hydranth Buds, Halves, Three-Quarters, Completes, Seniles, Empties, and Brokens

	1933	1934	1935	1936	1937	1938	1939
				Completes: Buds			
April	—	—	—	—	—	+.261	—.287
May	—	+.603	+.127	—.288	+.334	+.167	+.118
June	+.500	+.240	+.126	—.146	—.004	—.295	—.400
July	+.250	+.099	—.108	—.250	—.396	—.181	+.007
Aug.	+.162	+.103	—.030	—.395	—.455	—.300	—.014
Sept.	—.052	+.330	+.416	—.265	—.546	—.450	+.211
				Completes: Halves			
April	—	—	—	—	—	—.254	—.177
May	—	+.668	+.267	+.105	+.424	+.037	—.382
June	—.254	+.088	+.256	—.011	+.181	—.091	—.077
July	+.137	—.247	+.058	—.064	—.517	—.352	—.340
Aug.	—.295	—.314	+.123	+.180	—.043	—.239	—.354
Sept.	—.159	—.151	—.035	+.213	—.341	—.216	—.163
				Completes: Three-Quarters			
April	—	—	—	—	—	+.086	—.226
May	—	+.613	+.347	+.025	+.250	+.021	—.162
June	—.362	+.234	+.015	+.108	—.380	—.146	—.279
July	+.199	+.083	—.285	—.263	—.574	—.374	—.227
Aug.	—.298	+.407	—.239	—.256	—.047	—.198	—.093
Sept.	—.146	+.360	—.201	—.237	—.416	—.266	+.034
				Completes: Seniles			
April	—	—	—	—	—	—.161	—.362
May	—	+.080	—.138	—.113	—.109	+.101	—.147
June	—.447	+.053	—.150	—.204	+.008	—.358	—.001
July	—.180	—.092	—.312	—.434	—.259	—.301	—.028
Aug.	+.190	—.271	—.124	—.284	—.327	—.471	+.127
Sept.	—.235	+.017	+.154	—.569	—.263	—.137	+.006
				Completes: Empties			
April	—	—	—	—	—	+.045	—.070
May	—	+.053	+.047	—.065	—.022	—.051	—.480
June	+.031	+.205	—.127	—.222	—.237	—.146	—.085
July	—.038	—.211	—.178	—.268	—.472	—.049	—.009
Aug.	—.057	—.129	—.210	—.221	—.364	—.245	—.043
Sept.	+.003	+.119	+.430	—.348	—.140	—.301	+.062
				Completes: Brokens			
April	—	—	—	—	—	+.305	—.336
May	—	+.093	+.060	+.042	+.104	—.029	—.123
June	+.212	+.068	—.607	—.098	—.240	—.115	+.148
July	—.042	—.235	—.340	—.281	—.229	—.259	—.252
Aug.	+.185	—.194	—.366	—.369	—.239	—.149	—.082
Sept.	—.439	+.229	—.033	—.169	—.147	—.276	—.097
				Buds: Halves			
April	—	—	—	—	—	+.072	+.245
May	—	—.169	+.056	+.470	+.203	+.040	—.172
June	+.216	+.237	—.033	+.112	+.147	—.124	—.069
July	+.046	+.288	+.061	+.097	—.100	—.151	—.095
Aug.	+.183	—.061	—.013	+.198	+.139	—.152	—.186
Sept.	+.033	—.165	+.316	+.357	—.118	—.258	—.149

TABLE 4 (*continued*)

	1933	1934	1935	1936	1937	1938	1939
			Buds: Three-Quarters				
April	—	—	—	—	—	+.*299*	+.178
May	—	—.450	+.030	—.*254*	+.041	+.317	+.164
June	+.179	+.119	+.394	+.393	+.*201*	—.*167*	+.132
July	+.090	+.082	+.025	+.076	—.098	—.123	+.197
Aug.	+.443	—.142	—.056	—.078	+.315	—.117	+.461
Sept.	+.066	—.138	+.409	—.440	—.025	—.217	—.198
			Buds: Seniles				
April	—	—	—	—	—	+.*311*	—.105
May	—	+.110	—.163	—.128	+.126	—.060	+.096
June	+.073	—.267	+.325	+.085	+.040	+.102	+.166
July	—.077	+.137	—.024	+.129	—.139	+.098	—.424
Aug.	—.095	+.310	+.168	—.123	—.108	+.055	+.*213*
Sept.	+.314	+.207	—.025	—.218	+.090	—.*267*	—.266
			Buds: Empties				
April	—	—	—	—	—	+.089	—.130
May	—	+.240	—.010	—.422	—.101	+.179	+.*276*
June	+.118	—.110	—.060	+.134	—.*217*	—.006	+.181
July	—.104	+.056	—.035	—.107	—.223	+.*176*	—.*208*
Aug.	—.012	+.054	+.033	—.278	—.074	—.236	—.311
Sept.	+.193	—.[illegible]	—.333	—.056	—.031	—.350	—.068
			Buds: Brokens				
April	—	—	—	—	—	—.472	+.225
May	—	—.278	—.364	—.*237*	—.282	—.076	—.*334*
June	—.381	—.005	+.133	—.453	—.035	—.430	—.*240*
July	+.159	—.166	—.302	—.547	—.374	—.057	—.056
Aug.	—.259	—.292	—.335	—.491	—.297	—.499	—.378
Sept.	—.470	—.723	—.000	—.368	—.386	—.310	—.476
			Halves: Three-Quarters				
April	—	—	—	—	—	+.085	—.*360*
May	—	—.*259*	—.032	+.*268*	—.*191*	—.096	—.094
June	—.001	+.042	—.088	+.057	—.069	—.*214*	—.179
July	+.135	+.151	+.162	—.007	—.308	—.*177*	+.073
Aug.	+.078	+.235	+.095	+.084	—.*196*	—.115	—.117
Sept.	—.009	+.189	—.080	+.343	—.*237*	—.*286*	—.*353*
			Halves: Seniles				
April	—	—	—	—	—	—.110	—.082
May	—	—.213	+.060	+.040	+.168	+.049	—.136
June	+.137	+.116	+.091	+.152	+.*196*	+.086	+.062
July	+.150	—.078	—.053	+.071	+.125	—.010	+.151
Aug.	+.*253*	—.*189*	—.068	—.064	+.072	+.022	+.197
Sept.	—.012	—.197	+.017	+.162	—.003	—.059	+.085
			Halves: Empties				
April	—	—	—	—	—	—.032	+.189
May	—	+.013	—.117	+.*267*	+.116	—.010	—.106
June	—.033	—.012	+.026	—.*180*	+.054	—.*228*	+.079
July	+.092	+.109	+.*168*	+.023	—.405	+.091	+.120
Aug.	+.072	+.072	+.039	+.125	—.302	+.028	—.*245*
Sept.	—.064	+.*314*	+.*272*	—.058	—.314	—.183	+.286

TABLE 4 (*continued*)

	1933	1934	1935	1936	1937	1938	1939
			Halves: Brokens				
April	—	—	—	—	—	+.*314*	—.159
May	—	+.124	—.038	—.087	+.133	+.178	—.125
June	+.047	—.108	+.169	—.107	—.*198*	+.024	—.*204*
July	+.090	—.033	—.*201*	—.077	—.102	+.092	—.*236*
Aug.	+.174	—.*177*	—.275	—.122	+.150	—.037	—.286
Sept.	—.173	—.277	—.184	+.107	+.053	—.206	—.434
			Three-Quarters: Seniles				
April	—	—	—	—	—	+.112	—.007
May	—	—.083	+.*223*	—.013	+.057	+.136	+.113
June	—.342	+.095	+.061	+.098	—.083	+.013	—.045
July	+.349	+.082	+.*209*	—.*199*	—.088	+.009	+.081
Aug.	+.010	+.489	—.060	+.016	—.016	—.*182*	—.114
Sept.	+.037	+.*274*	+.125	—.064	—.392	—.031	—.078
			Three-Quarters: Empties				
April	—	—	—	—	—	—.200	+.100
May	—	+.161	+.006	—.313	+.089	+.115	—.206
June	+.186	+.153	—.*210*	+.082	—.010	+.035	—.114
July	+.205	+.060	—.039	+.056	—.*207*	—.130	+.274
Aug.	+.159	+.001	—.110	+.094	—.090	+.007	+.148
Sept.	—.167	—.145	+.012	—.003	+.117	—.221	+.104
			Three-Quarters: Brokens				
April	—	—	—	—	—	+.114	—.484
May	—	+.066	—.*204*	—.043	—.357	—.106	+.051
June	+.126	—.011	—.099	+.046	—.*212*	—.018	—.019
July	—.182	—.270	—.336	—.108	—.*193*	—.046	—.120
Aug.	—.007	—.166	—.358	—.327	—.165	—.*197*	+.089
Sept.	—.278	—.*297*	—.*241*	—.*289*	—.183	—.382	—.*381*
			Seniles: Empties				
April	—	—	—	—	—	+.244	+.189
May	—	—.150	+.155	+.*222*	+.315	+.300	+.*122*
June	+.216	+.158	+.087	+.254	+.062	+.184	+.*195*
July	—.035	+.073	—.046	+.031	—.045	+.306	+.181
Aug.	+.143	+.071	—.144	—.063	+.107	+.*187*	+.*272*
Sept.	+.091	+.167	—.166	—.*240*	+.172	—.098	+.150
			Seniles: Brokens				
April	—	—	—	—	—	+.443	+.077
May	—	+.*346*	+.168	—.205	+.270	+.285	+.020
June	+.*257*	+.092	+.040	+.087	+.164	+.049	—.016
July	+.481	+.052	—.076	+.094	—.126	—.075	+.317
Aug.	—.001	+.143	—.084	—.051	+.160	+.025	+.*256*
Sept.	—.078	+.*259*	+.022	—.028	+.032	—.125	+.*312*
			Empties: Brokens				
April	—	—	—	—	—	—.000	+.161
May	—	+.182	—.030	+.193	+.014	+.042	+.194
June	+.098	+.173	+.122	+.474	+.117	+.*214*	+.256
July	+.297	+.*227*	+.062	+.262	+.033	+.060	+.352
Aug.	+.143	+.*204*	—.091	+.035	+.137	+.129	—.014
Sept.	+.141	+.140	+.*232*	+.309	+.082	—.021	+.228

TABLE 5

THE r_{zy} STANDARD (Sr) TO THE DEGREES OF FREEDOM OF THE HYDRANTH VARIATES COMPUTED THROUGH t BY MONTH BY YEAR

	April		May		June		July		August		September	
	N	Sr	N	Sr	N	Sr	N	Sr	N	Sr	N	Sr
1933	—	—	—	—	61	.327	86	.276	100	.256	94	.264
1934	—	—	35	.428	122	.232	112	.242	131	.224	58	.335
1935	—	—	95	.263	114	.240	138	.219	129	.226	71	.304
1936	—	—	83	.281	120	.234	139	.218	118	.236	67	.312
1937	—	—	125	.230	128	.227	138	.219	115	.239	86	.276
1938	47	.372	103	.253	104	.252	124	.231	126	.229	68	.310
1939	44	.376	49	.364	102	.254	94	.264	97	.260	39	.407

N—Number of Variates

are italicized in tables 3 and 4. Here the coefficient is considered indicative if divisible 3 or more times by its Probable Error. All higher value coefficients are *Sr*-valid.

To summarize: Tables 3, 4, and 5 provide the base data for estimate of hydranth inter-structural correlations in Obelia colony populations.

Table 3 gives the Zero Order coefficients of correlation of the 21 couplings by month by year. Each measures the extent of statistical association which is expressed by the stated pair of structures under the influence of all the other members of the hydranth family of structures. It is the association expressed within the community of structures. It is the communal association.

Table 4 gives the 5th Order coefficients. As derived from the Zero Order data. With which it is homologous. For each of the 21 couplings. By month by year. Each coefficient measures the extent of statistical association which is expressed by the stated pair free from influence of all the other members of the hydranth family of structures. It is the association *sui generis*. The intrinsic association.

Table 5 provides a set of Standard values of correlation wherewith the observed values of each month of each year may be tested for statistical validity. When the observed coefficient is the same or greater than the Standard coefficient: association between the 2 structures is statistically established. When the observed coefficient is less than the Standard value: association is not statistically established on this base.

Analysis and Comment

Over-all Relations: When the coefficients of tables 3 and 4 are tested against the Standard values of table 5, it is found that statistically valid association between any 2 structures is not expressed in all the 36 opportunities therefor. Obviously only the coefficients which meet the test can be used for estimate of association.

Of primary interest is information on the nature of the association, i.e. whether this be conjunctive or disjunctive.

The tables show that of those which do meet the test in the case of any given coupling some may show negative correlation and some may show positive. Apparently decision as to the nature of association between any 2 structures must be gotten from the relative frequency with which valid correlation is positive and negative.

Such being the case estimate of the likelihood, extent, and nature of association will be based on the consistency with which the valid coefficients of each coupling are positive or negative. This involves setting up a tabulation of the frequency with which correlation is validly positive, validly negative, and unvalid, among the 36 coefficients of each coupling by month by year. Table 6 gives such frequency data for the Zero Order coefficients. Table 7 gives them for the 5th Order material.

The *tr* lines give the frequency of *Sr*-valid coefficients: the *PE* lines that of the *PE*-valid. The latter of course include the former. Since weighting is possible, 4 combinings are made.

The 1st gives for each year separately the frequency with which the months of record in that year show dominant positive, negative, and no correlation. Thus—the Zero Order data for completes-buds in 1937 show negative correlation dominated in 3 of the 5 months: positive in 1: no correlation in 1. And so on similarly.

The 2nd gives for each coupling the frequency of positive, negative, and no correlation dominance among the 36 months of record. Thus—under ALL, the *tr* data for Zero Order completes-buds show negative correlation dominated in 7 of the 36: positive in 6: and no correlation in 23. And so on similarly.

The 3rd gives the frequency with which positive, negative, and no correlation is dominant among the months of yearly record. Thus—table 3 shows that Zero Order *Sr*-valid correlation between completes and buds was negative more often than positive in April, August, and

TABLE 6

DISTRIBUTION OF ZERO ORDER CORRELATION COEFFICIENTS EXHIBITED BY OBELIA HYDRANTH BUDS, HALVES, THREE-QUARTERS, COMPLETES, SENILES, EMPTIES, AND BROKENS ACCORDING TO WHETHER THEY ARE POSITIVE, NEGATIVE, OR UNINDICATED

	1933			1934			1935			1936			1937			1938			1939			Combinings by All			Combinings by Month			Combinings by Year			Trend of r_{xy}
	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	
Completes: Buds																															
tr	2	0	2	2	0	3	0	0	5	0	1	4	1	3	1	0	1	5	1	2	3	6	7	23	2	3	1	2	4	1	Neg.
PE	2	0	2	3	0	2	2	0	3	0	1	4	1	3	1	0	3	3	2	2	2	10	9	17	2	2	2	3	3	1	0
Completes: Halves																															
tr	0	1	3	1	0	4	2	0	3	0	0	5	2	1	2	0	2	4	0	2	4	5	6	25	2	2	2	3	3	1	0
PE	0	2	2	1	2	2	2	0	3	1	0	4	2	1	2	0	2	4	0	3	3	6	10	20	1	2	3	3	4	0	Neg.
Completes: Three-Quarters																															
tr	0	1	3	4	0	1	1	1	3	0	0	5	0	3	2	0	1	5	0	2	4	5	8	23	1	2	3	1	4	2	Neg.
PE	0	1	3	4	0	1	1	1	3	0	2	3	1	3	1	0	1	5	0	2	4	6	10	20	1	3	2	1	5	1	Neg.
Completes: Seniles																															
tr	0	1	3	0	0	5	0	1	4	0	4	1	0	2	3	0	3	3	0	2	4	0	13	23	0	5	1	0	6	1	Neg.
PE	0	1	3	0	0	5	0	2	3	0	4	1	0	3	2	0	3	3	0	2	4	0	15	21	0	5	1	0	6	1	Neg.
Completes: Empties																															
tr	0	0	4	2	2	1	1	1	3	0	3	2	0	3	2	0	2	4	0	2	4	3	13	20	0	3	3	0	4	3	Neg.
PE	0	0	4	2	2	1	1	2	2	0	4	1	0	3	2	0	3	3	0	2	4	3	16	17	0	3	3	0	5	2	Neg.
Completes: Brokens																															
tr	0	1	3	0	2	3	0	3	2	0	3	2	0	2	3	0	1	5	1	2	3	1	14	21	0	5	1	0	7	0	Neg.
PE	0	1	3	0	2	3	0	3	2	0	4	1	0	2	3	0	1	5	1	3	2	1	16	19	0	5	1	0	7	0	Neg.
Buds: Halves																															
tr	0	0	4	2	0	3	1	0	4	3	0	2	1	0	4	0	0	6	0	1	5	7	1	28	4	0	2	4	1	2	Pos.
PE	1	0	3	3	0	2	1	0	4	5	0	0	1	0	4	0	0	6	0	1	5	11	1	24	5	0	1	5	1	1	Pos.
Buds: Three-Quarters																															
tr	1	0	3	0	0	5	2	0	3	1	0	4	2	0	3	1	0	5	2	0	4	9	0	27	4	0	2	6	0	1	Pos.
PE	2	0	2	1	0	4	3	0	2	2	1	2	5	0	0	2	0	4	2	0	4	17	1	18	6	0	0	7	0	0	Pos.
Buds: Seniles																															
tr	1	0	3	1	1	3	1	0	4	0	0	5	0	0	5	0	0	6	0	2	4	3	3	30	1	1	4	2	1	4	0
PE	1	0	3	1	1	3	2	1	2	0	0	5	0	0	5	1	0	5	1	2	3	6	4	26	2	1	3	3	1	3	Pos.
Buds: Empties																															
tr	0	0	4	0	0	5	0	0	5	0	3	2	0	1	4	1	1	4	0	2	4	1	7	28	0	5	1	0	3	4	Neg.
PE	0	0	4	1	0	4	0	0	5	0	3	2	0	1	4	2	2	2	0	3	3	3	9	24	1	4	1	1	3	3	Neg.
Buds: Brokens																															
tr	0	3	1	0	2	3	0	3	2	0	5	0	0	4	1	0	2	4	0	4	2	0	23	13	0	5	1	0	7	0	Neg.
PE	0	3	1	0	3	2	0	4	1	0	5	0	0	4	1	0	3	3	1	5	0	1	27	8	0	5	1	0	7	0	Neg.

TABLE 6 (*continued*)

	1933			1934			1935			1936			1937			1938			1939			Combinings by All			Combinings by Month			Combinings by Year			Trend of r_{xy}
	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	
Halves: Three-Quarters																															
tr	1	0	3	0	0	5	1	0	4	0	0	5	0	0	5	0	0	6	0	0	6	2	0	34	2	0	4	2	0	5	Pos.
PE	2	0	2	1	0	4	2	0	3	0	0	5	0	0	5	0	1	5	1	1	4	6	2	28	3	2	1	3	1	3	Pos.
Halves: Seniles																															
tr	1	0	3	0	0	5	0	0	5	0	0	5	2	0	3	0	0	6	1	0	5	4	0	32	2	0	4	3	0	4	Pos.
PE	3	0	1	0	0	5	0	0	5	0	0	5	3	0	2	1	0	5	1	0	5	8	0	28	4	0	2	4	0	3	Pos.
Halves: Empties																															
tr	0	0	4	0	0	5	0	0	5	0	1	4	0	1	4	0	0	6	1	0	5	1	2	33	1	2	3	1	2	4	Neg.
PE	0	0	4	1	0	4	0	0	5	0	1	4	0	3	2	1	1	4	1	1	4	3	6	27	1	3	2	1	2	4	Neg.
Halves: Brokens																															
tr	0	0	4	0	0	5	0	2	3	0	2	3	0	0	5	0	0	6	0	0	6	0	4	32	0	3	3	0	2	5	Neg.
PE	1	1	2	0	1	4	0	2	3	0	3	2	1	1	3	3	0	3	0	1	5	5	9	22	3	3	0	1	4	2	Neg.
Three-Quarters: Seniles																															
tr	1	0	3	1	0	4	1	0	4	0	0	5	0	0	5	0	0	6	0	0	6	3	0	33	2	0	4	3	0	4	Pos.
PE	1	0	3	1	0	4	1	0	4	1	0	4	0	1	4	0	0	6	0	0	6	4	1	31	3	1	2	4	1	2	Pos.
Three-Quarters: Empties																															
tr	0	0	4	0	0	5	0	1	4	0	0	5	0	0	5	0	0	6	1	0	5	1	1	34	1	1	4	1	1	5	0
PE	2	0	2	2	0	3	0	2	3	0	1	4	0	0	5	1	0	5	1	0	5	6	3	27	3	1	2	4	2	1	Pos.
Three-Quarters: Brokens																															
tr	0	1	3	0	2	3	0	3	2	0	1	4	0	2	3	0	1	5	0	1	5	0	11	25	0	5	1	0	7	0	Neg.
PE	0	1	3	0	3	2	0	4	1	0	1	4	0	3	2	0	1	5	0	2	4	0	15	21	0	5	1	0	7	0	Neg.
Seniles: Empties																															
tr	0	0	4	1	0	4	0	0	5	2	0	3	2	0	3	4	0	2	2	0	4	11	0	25	5	0	1	5	0	2	Pos.
PE	1	0	3	1	0	4	0	0	5	3	0	2	2	0	3	4	0	2	4	0	2	15	0	21	5	0	1	6	0	1	Pos.
Seniles: Brokens																															
tr	1	0	3	0	0	5	0	0	5	2	0	3	2	0	3	1	0	5	2	0	4	8	0	28	5	0	1	5	0	2	Pos.
PE	2	1	1	0	0	5	2	0	3	2	0	3	2	0	3	2	0	4	3	0	3	13	1	22	6	0	0	6	0	1	Pos.
Empties: Brokens																															
tr	1	0	3	2	0	3	1	0	4	4	0	1	1	0	4	1	0	5	2	0	4	12	0	24	5	0	1	7	0	0	Pos.
PE	1	0	3	3	0	2	2	0	3	5	0	0	3	0	2	2	0	4	3	0	3	19	0	17	5	0	1	7	0	0	Pos.

TABLE 7

DISTRIBUTION OF 5TH ORDER CORRELATION COEFFICIENTS EXHIBITED BY OBELIA HYDRANTH BUDS, HALVES, THREE-QUARTERS, COMPLETES, SENILES, EMPTIES, AND BROKENS ACCORDING TO WHETHER THEY ARE POSITIVE, NEGATIVE, OR UNINDICATED

	1933			1934			1935			1936			1937			1938			1939			Combinings by All			Combinings by Month			Combinings by Year			Trend of r_{xy}
	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	
Completes: Buds																															
tr	1	0	3	2	0	3	1	0	4	0	3	2	1	3	1	0	3	3	0	1	5	5	10	21	1	4	1	3	4	0	Neg.
PE	2	0	2	3	0	2	1	0	4	0	4	1	1	3	1	0	4	2	0	2	6	7	13	16	1	5	0	3	4	0	Neg.
Completes: Halves																															
tr	0	1	3	1	2	2	2	0	3	0	0	5	1	2	0	0	2	4	0	3	3	4	10	22	2	3	1	1	5	1	Neg.
PE	0	2	2	1	2	2	2	0	3	0	0	5	2	2	0	0	2	4	0	3	3	5	11	20	2	3	1	1	4	2	Neg.
Completes: Three-Quarters																															
tr	0	2	2	4	0	1	1	2	2	0	2	3	1	3	1	0	1	5	0	1	5	6	11	19	1	3	2	1	6	0	Neg.
PE	0	2	2	4	0	1	1	2	2	0	3	2	1	3	1	0	3	3	0	2	4	6	15	15	1	4	1	1	6	0	Neg.
Completes: Seniles																															
tr	0	1	3	0	1	4	0	1	4	0	3	2	0	2	3	0	3	3	0	0	6	0	11	25	0	4	2	0	6	1	Neg.
PE	0	2	2	0	1	4	0	1	4	0	4	1	0	3	2	0	3	3	0	1	5	0	15	21	0	5	1	0	7	0	Neg.
Completes: Empties																															
tr	0	0	4	0	0	5	1	0	4	0	2	3	0	3	2	0	1	5	0	1	5	1	7	28	0	4	2	1	4	2	Neg.
PE	0	0	4	1	1	3	1	2	2	0	4	1	0	3	2	0	2	4	0	1	5	2	13	21	0	5	1	0	5	2	Neg.
Completes: Brokens																															
tr	0	1	3	0	0	5	0	3	2	0	2	3	0	3	2	0	1	5	0	0	6	0	10	26	0	4	2	0	5	2	Neg.
PE	0	1	3	0	2	3	0	3	2	0	2	3	0	3	2	1	2	3	0	2	4	1	15	20	0	4	2	0	7	0	Neg.
Buds: Halves																															
tr	0	0	4	2	0	3	1	0	4	2	0	3	0	0	5	0	0	6	0	0	6	5	0	31	4	0	2	3	0	4	Pos.
PE	0	0	4	2	0	3	1	0	4	3	0	2	1	0	4	0	1	5	0	0	6	7	1	28	4	0	2	4	1	2	Pos.
Buds: Three-Quarters																															
tr	1	0	3	0	1	4	2	0	3	1	1	3	1	0	4	1	0	5	1	0	5	7	2	27	2	1	3	5	1	1	Pos.
PE	1	0	3	0	1	4	2	0	3	1	2	2	2	0	3	2	0	4	1	0	5	9	3	24	3	1	2	5	2	0	Pos.
Buds: Seniles																															
tr	1	0	3	1	1	3	1	0	4	0	0	5	0	0	5	0	0	6	0	1	5	3	2	31	2	1	3	2	1	4	Pos.
PE	1	0	3	1	1	3	1	0	4	0	0	5	0	0	5	1	1	4	1	1	4	5	3	28	3	1	2	2	0	5	Pos.
Buds: Empties																															
tr	0	0	4	0	0	5	0	1	4	0	2	3	0	1	4	0	2	4	0	1	5	0	7	29	0	4	2	0	5	2	Neg.
PE	0	0	4	0	0	5	0	1	4	0	2	3	0	2	3	1	2	3	1	2	3	2	9	25	0	4	2	0	5	2	Neg.
Buds: Brokens																															
tr	0	3	1	0	2	3	0	3	2	0	4	1	0	4	1	0	4	2	0	2	4	0	22	14	0	6	0	0	7	0	Neg.
PE	0	3	1	0	2	3	0	3	2	0	5	0	0	4	1	0	4	2	0	4	2	0	25	11	0	6	0	0	7	0	Neg.

TABLE 7 (*continued*)

	1933			1934			1935			1936			1937			1938			1939			All			Combinings by Month			Year			Trend of r_{xy}
	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	+	−	0	
Halves: Three-Quarters																															
tr	0	0	4	1	0	4	0	0	5	1	0	4	0	1	4	0	0	6	0	0	6	2	1	33	2	1	3	2	1	4	Pos.
PE	0	0	4	1	0	4	0	0	5	2	0	3	0	4	1	0	3	3	0	2	4	3	9	24	0	4	2	2	3	2	Neg.
Halves: Seniles																															
tr	0	0	4	0	0	5	0	0	5	0	0	5	0	0	5	0	0	6	0	0	6	0	0	36	0	0	6	0	0	7	0
PE	1	0	3	0	1	4	0	0	5	0	0	5	1	0	4	0	0	6	0	0	6	2	1	34	1	0	5	2	1	4	Pos.
Halves: Empties																															
tr	0	0	4	0	0	5	0	0	5	0	0	5	0	3	2	0	0	6	0	0	6	0	3	33	0	3	3	0	1	6	Neg.
PE	0	0	4	1	0	4	2	0	3	1	1	3	0	3	2	0	1	5	0	1	5	4	6	26	2	2	2	2	3	2	Neg.
Halves: Brokens																															
tr	0	0	4	0	0	5	0	1	4	0	0	5	0	0	5	0	0	6	0	2	4	0	3	33	0	2	4	0	2	5	Neg.
PE	0	0	4	0	2	3	0	2	3	0	0	5	0	1	4	1	0	5	0	4	2	1	9	26	1	4	1	1	4	2	Neg.
Three-Quarters: Seniles																															
tr	1	1	2	1	0	4	0	0	5	0	0	5	0	1	4	0	0	6	0	0	6	2	2	32	2	2	2	1	1	5	0
PE	1	1	2	2	0	3	2	0	3	0	1	4	0	1	4	0	1	5	0	0	6	5	4	27	2	1	3	2	3	2	0
Three-Quarters: Empties																															
tr	0	0	4	0	0	5	0	0	5	0	1	4	0	0	5	0	0	6	1	0	5	1	1	34	1	1	4	1	1	5	0
PE	0	0	4	0	0	5	0	1	4	0	1	4	0	1	4	0	0	6	1	0	5	1	3	32	0	2	4	1	3	3	Neg.
Three-Quarters: Brokens																															
tr	0	1	3	0	1	4	0	2	3	0	1	4	0	1	4	0	1	5	0	1	5	0	8	28	0	5	1	0	7	0	Neg.
PE	0	1	3	0	2	3	0	4	1	0	2	3	0	3	2	0	2	4	0	2	4	0	16	20	0	6	0	0	7	0	Neg.
Seniles: Empties																															
tr	0	0	4	0	0	5	0	0	5	1	0	4	1	0	4	2	0	4	1	0	5	5	0	31	4	0	2	4	0	3	Pos.
PE	0	0	4	0	0	5	0	0	5	2	1	2	1	0	4	3	0	3	2	0	4	8	1	27	4	1	1	4	0	3	Pos.
Seniles: Brokens																															
tr	1	0	3	0	0	5	0	0	5	0	0	5	1	0	4	2	0	4	1	0	5	5	0	31	3	0	3	4	0	3	Pos.
PE	2	0	2	2	0	3	0	0	5	0	0	5	1	0	4	2	0	4	3	0	3	10	0	26	6	0	0	5	0	2	Pos.
Empties: Brokens																															
tr	1	0	3	0	0	5	0	0	5	3	0	2	0	0	5	0	0	6	2	0	4	6	0	30	3	0	3	3	0	4	Pos.
PE	1	0	3	2	0	3	1	0	4	3	0	2	0	0	5	1	0	5	2	0	4	10	0	26	4	0	2	6	0	1	Pos.

TABLE 8

FREQUENCY WITH WHICH THE WEEK-TO-WEEK DIRECTION OF CHANGE IN % OF ONE STATED VARIABLE IS THE SAME AS OR OPPOSITE TO THAT OF THE OTHER STATED VARIABLE

	126 Weeks						37 Month-Years						23 Periods									Trend
	Totals			Months			Totals			Months			Totals			Months			7 Years			of
	S	O	N	S	O	N	S	O	N	S	O	N	S	O	N	S	O	N	S	O	N	Concord
Completes: Buds																						
Sig	14	56	56	—	6	—	3	27	7	—	6	—	1	20	2	—	6	—	—	6	1	Neg
Ind	30	88	8	—	6	—	3	27	7	—	6	—	1	21	1	—	6	—	—	7	—	Neg
Completes: Halves																						
Sig	12	61	53	—	6	—	3	27	7	—	6	—	2	18	3	—	5	1	—	7	—	Neg
Ind	28	88	10	—	5	1	4	28	5	—	5	1	2	18	3	1	5	—	—	7	—	Neg
Completes: Three-Quarters																						
Sig	10	63	53	—	5	1	1	31	4	—	5	1	1	19	3	—	6	—	—	7	—	Neg
Ind	33	86	7	—	6	—	3	27	7	—	6	—	1	19	3	—	6	—	—	6	1	Neg
Completes: Seniles																						
Sig	23	57	46	—	6	—	7	22	8	—	5	1	2	16	5	—	5	1	—	6	1	Neg
Ind	37	76	13	—	5	1	11	23	3	—	3	3	2	16	5	1	5	—	1	6	—	Neg
Completes: Empties																						
Sig	26	56	44	1	4	1	7	24	6	1	4	1	5	15	3	—	4	2	—	7	—	Neg
Ind	40	75	11	—	5	1	8	25	4	—	5	1	4	15	4	—	5	1	—	6	1	Neg
Completes: Brokens																						
Sig	33	43	50	1	4	1	14	19	4	1	3	2	7	14	2	1	4	1	1	4	2	Neg
Ind	54	60	12	2	4	—	13	19	5	1	3	2	8	14	1	1	4	1	1	2	4	Neg
Buds: Halves																						
Sig	42	29	55	3	1	2	19	10	9	3	1	2	15	6	2	4	1	1	5	1	1	Pos
Ind	67	47	12	4	1	1	17	8	12	3	1	2	15	6	2	5	1	—	4	1	2	Pos
Buds: Three-Quarters																						
Sig	57	23	46	4	—	2	23	8	6	3	—	3	14	3	6	4	1	1	5	—	2	Pos
Ind	75	41	10	4	1	1	20	9	8	3	1	2	14	5	4	4	1	1	5	1	1	Pos
Buds: Seniles																						
Sig	36	46	44	—	4	2	10	18	9	—	3	3	6	9	8	1	4	1	2	4	1	Neg
Ind	50	61	15	1	3	2	13	17	7	—	1	5	7	13	3	1	4	1	1	3	3	Neg
Buds: Empties																						
Sig	36	54	36	1	5	—	12	17	8	—	3	3	6	13	4	1	4	1	1	5	1	Neg
Ind	48	67	11	—	5	1	10	19	8	—	4	2	6	14	3	1	4	1	1	5	1	Neg
Buds: Brokens																						
Sig	21	60	45	1	5	—	6	27	4	1	5	—	2	14	7	1	5	—	—	7	—	Neg
Ind	37	76	13	1	5	—	6	23	8	1	4	1	4	15	4	1	5	—	—	7	—	Neg

S—Same Direction of Change: O—Opposite Direction of Change: N—No Comparison: Sig—Significant: Ind—Indicative

TABLE 8 (*continued*)

	126 Weeks						37 Month-Years						23 Periods						7 Years			Trend of Concord
	Totals			Months			Totals			Months			Totals			Months						
	S	O	N	S	O	N	S	O	N	S	O	N	S	O	N	S	O	N	S	O	N	
Halves: Three-Quarters																						
Sig	56	22	48	4	1	1	21	9	7	2	—	4	14	2	7	4	1	1	6	1	—	Pos
Ind	73	41	12	5	1	—	22	9	6	3	—	3	14	4	5	5	1	—	4	2	1	Pos
Halves: Seniles																						
Sig	49	34	43	4	2	—	20	11	6	4	—	2	11	6	6	4	2	—	4	3	—	Pos
Ind	65	44	17	4	2	—	21	11	5	2	—	4	13	5	5	4	2	—	4	2	1	Pos
Halves: Empties																						
Sig	52	36	38	3	3	—	21	14	2	3	3	—	10	8	5	3	3	—	5	—	2	Pos
Ind	67	44	15	3	1	2	20	11	6	3	2	1	13	8	2	3	2	1	5	1	1	Pos
Halves: Brokens																						
Sig	42	42	42	3	1	2	17	13	7	2	1	3	8	12	3	2	3	1	1	2	4	0
Ind	55	55	16	3	3	—	16	14	7	3	1	2	10	11	2	3	3	—	1	2	4	0
Three-Quarters: Seniles																						
Sig	55	36	35	4	1	1	21	12	4	4	1	1	11	5	7	4	1	1	4	1	2	Pos
Ind	62	50	14	4	1	1	17	12	8	4	1	1	12	9	2	4	2	—	3	3	1	Pos
Three-Quarters: Empties																						
Sig	44	48	34	2	3	1	15	14	8	1	1	4	7	11	5	2	4	—	2	4	1	Neg
Ind	53	60	13	1	3	2	13	15	9	—	2	4	8	11	4	1	3	2	3	4	—	Neg
Three-Quarters: Brokens																						
Sig	31	57	38	—	4	2	10	23	4	—	3	3	2	14	7	—	4	2	1	5	1	Neg
Ind	45	66	15	1	3	2	10	21	6	1	3	2	6	11	6	2	3	1	1	4	2	Neg
Seniles: Empties																						
Sig	73	30	23	5	—	1	26	6	5	4	—	2	18	4	1	4	—	2	—	7	—	Pos
Ind	79	31	16	5	—	1	27	6	4	4	—	2	18	4	1	4	—	2	—	7	—	Pos
Seniles: Brokens																						
Sig	62	33	31	4	—	2	23	6	8	4	—	2	14	5	4	4	1	1	5	—	2	Pos
Ind	69	38	19	4	—	2	24	5	8	5	—	1	14	5	4/	4	1	1	6	—	1	Pos
Empties: Brokens																						
Sig	66	35	25	5	1	—	22	8	7	4	1	1	16	3	4	5	1	—	6	—	1	Pos
Ind	70	41	15	5	1	—	22	9	6	3	1	2	14	4	5	5	1	—	6	—	1	Pos

S—Same Direction of Change: O—Opposite Direction of Change: N—No Comparison: Sig—Significant: Ind—Indicative

September: positive more often than negative in May and July: and that neither dominated in June. So negative trend ruled in 3 of the 6 months: positive in 2: and no correlation in 1. Such is the record under the Month heading. And so on similarly.

The 4th gives the frequency with which positive, negative, and no correlation is dominant among the 7 years of record. Thus—the *tr* data of the Zero Order completes-buds show negative correlation dominant in 4 of the 7 years: positive in 2: no correlation in 1. Such is the record under the Year heading. And so on similarly.

Estimate of the trend of association expressed by each coupling is given in the last column. It is based on the consistency of trend exhibited in the 4 combinings.

Supplementary data are useful. They also add to completeness of record. Tables 5 to 11 of the season study (Hammett and Hammett, 1945) give the percentages of buds, halves, etc. in those populations week by week. If the direction of change in per cent of one structure from one week to the next is the same or opposite to that of another with fair consistency, some sort of relation between the 2 is obvious. If the 2 increase and decrease simultaneously: positive correlation is indicated. If one increases as the other decreases, and vice versa: negative correlation is indicated.

So table 8 has been prepared. This gives for each coupling the frequency with which week-to-week change in per cent of one structure is the same as or opposite to that of the other (in direction). And the frequency of no comparison. The procedure and rationale of combinings by 126 Weeks: 37 Month-Years: 23 Periods: and 7 Years is given in the season study. Here 5 per cent difference is arbitrarily taken as significant: any change as indicative.

The *Sig.* lines give the frequency of significant change: the *Ind.* lines the indicative. Numbers under *S* show the frequency of positive correlation: those under *O* of negative: and those under *N* of no comparison.

The last column gives estimate of the nature of the association. It is based on the consistency with which a trend is exhibited in the groupings. Thus—completes and buds are taken to be negatively correlated because the direction of change in percentage of one is opposite to that of the other in overwhelming frequency in all groupings. And so on similarly.

Correlation in percentage change must be used with caution. It derives from relative quantities which are numerically interdependent. In such, spurious correlation is rampant. Less danger is had in the correlation coefficients. These derive from absolute quantities which are numerically independent. These facts will not be neglected in conclusion.

Tables 6 and 7 show that statistically valid correlation is more honored in the breach than in the observance. But interest here is not in the intensity of association expressed by each pair of structures, as measured by the magnitude of their coefficients of correlation. Nor is it in the capacity of each to associate, as measured by the frequency with which statistically valid correlation is exhibited among the 36 possibilities therefor. Instead it is in whether the trend of association which is expressed is towards conjunctivity or disconjunctivity. And this is shown by the dominance of positive or negative correlation coefficients among those which are statistically significant.

Tables 6 and 7 give the frequency of those correlations that come to expression. Decision is based on the consistency with which these exhibit a trend. Consistency is an acceptable canon for estimate. This procedure may cause a raising of eyebrows by some. But "Unthinking subservience to the conventions of statistical and probability theory, is not the part of wisdom" (Pearl, 1940). Common sense does have a role.

The foregoing clears away any possibility of misunderstanding of the material used for decision. Detailed recital of all the bits of information provided by tables 6, 7, and 8 would be wasted work. First, because nobody would reach such a pedestrian presentation. And second, because anybody wanting knowledge of the minutiae will go to the tables anyhow. So analysis will concern itself with the broad over-all picture, and details will be left to those who like jackstraws.

Tables 6 and 7 give ample evidence that there is statistical association between hydranth structures. This gives quantitative statement to the qualitative observation of relationship.

On one basis or another each hydranth structure exhibits some trend of statistical association with each of the others. Thus the inferential postulate that an Obelia colony is a concinnate aggregate of inter-related hydranth structures is quantitatively established.

The character of these relations is the next question. Qualitative

observation indicates that the composition of an Obelia colony population is the resultant of balance between the growth, maintenance, and dissolution of the component hydranths (Hammett and Hammett, 1945). The implication is that the becoming of growth expressing structures is opposed by or to that of the maintenance and/or dissolution expressing structures. Quantitative evidence is wanted.

Such can be gotten from record of relations in space of how the number of one structure varies from population to population in relation to variations in number of another structure. This is what is here given. Or it can be gotten from record of relative progression of hydranths from initial to subsequent states within populations in time. Or record as is given in the amino-acid and other studies, q.v. That will be the subject of the next report.

Since the present data are of relations in space the allocation of structures is based on being. The buds, halves, and three-quarters are denominators of growth: the completes are denominators of maintenance: and the seniles, empties, and brokens are denominators of dissolution (Hammett, 1933: 1943a). Tables 6, 7, and 8 show the following:—

1. The buds, halves, and three-quarters tend to be negatively correlated with the completes. This is the trend in 16 of the 18 expressions. Thus the denominators of growth are statistically opposed to or by the denominator of maintenance. Which is quantitative evidence of balancing between growth and maintenance in colony populations.

The negative correlation between the product-expressions of growth and the denominator of maintenance is statistical evidence of antagonism between the 2 activities. It is thus statistical evidence consistent with Blumenfelds (1944) observations. But whether it means his postulate that function (maintenance) restrains growth is the whole story, is another matter. Though the probability is that this is the case. As will be indicated shortly.

2. The completes tend to be negatively correlated with the seniles, empties, and brokens. This is the trend in all 18 expressions. Thus the denominator of maintenance is statistically opposed to or by the denominators of dissolution. Which is quantitative evidence of balancing between maintenance and dissolution in colony population.

3. The buds, halves, and three-quarters tend to be negatively cor-

related with the empties and brokens. This is the trend in 29 of the 36 expressions. No trend is shown in 4: positive in 3. The denominators of growth are thus statistically opposed to or by denominators of dissolution. Which is quantitative evidence of balancing between growth and dissolution in colony populations.

The data thus give quantitative evidence that colony composition is the resultant of balance between the growth, maintenance, and dissolution of its component hydranths. Q.E.D.

4. Tables 6, 7, and 8 show the buds, halves, and three-quarters tend to be positively correlated with each other. The trend occurs in 17 of the 18 possibilities. This, combined with the fact these structures tend to be negatively correlated with the completes, empties, and brokens, is quantitative evidence these denominators of growth constitute an intra-associated group within the galaxy of inter-structure associations of the colony as a whole.

5. The tables also show the seniles, empties, and brokens tend to be positively correlated one with the other. The trend occurs in all 18 possibilities. This, combined with the fact the empties, and brokens tend to be negatively correlated with the denominators of growth, and all tend to negative correlation with the completes, is quantitative evidence the denominators of dissolution, also, constitute an intra-associated group within the galaxy of inter-structure associations of the colony as a whole.

These group data give quantitative evidence that a hydranth population is both an assembly of inter-related structures, and a composite of inter-related groups of structures; the members of which are specifically intra-related as a group, and integrated with the population as a whole through their relations with the structures outside the group.

Observation shows that an Obelia colony is first, last, and all the time a colony of mature feeding animals, to the establishment and continuance of which all growth and dissolution are tuned. The trend to negative correlation of all other hydranth structures with the completes is quantitative backing of this concept of colony holism.

General observation teaches that maintenance is primary in organismic economy. It persists in the face of conditions inhibitive of growth. It is the base activity when growth has ceased in the natural course of events. And it continues unto death despite senile decay

(Brody, 1945). The trend to negative correlation of the denominators of growth, and the denominators of dissolution with the denominator of maintenance is quantitative evidence that this principle is in force in Obelia colonies as elsewhere. It is also quantitative exposition that self-preservation is the first law of living.

The fact that denominators of growth tend to be opposed by or to denominators of dissolution coincides with records of physical and chemical differences. Thus—

Burr and Hammett (1939) found that voltage-gradients of growth denominators are opposite in sign to those of dissolution denominators. Hammett and Padis (1935) found the direction of hydroplasmic streaming to be *out into the growing structures; and down away from the disintegrating*. And Hammett and Chapman (1938) showed that growing hydranths build free amino-acids into their substance: while disintegrating hydranths give them up as they catabolize. These records give concinnate demonstration of oppositeness of growth and dissolution denominators. That the correlation data show the same is adequate evidence the consistency procedure yields reliable indices to inter-structure relations in colony populations.

Observation and experiment show that hydranth growth structures are busy with constructive substance increase, or anabolism; and dissolution structures engage in destructive substance decrease, or catabolism (Hammett, 1933: 1943a: Hammett and Padis, 1935: Hammett and Chapman, 1938). So the trend to negative correlation of the denominators of growth with denominators of dissolution is a nice quantitative statement of the generally established fact that anabolism and catabolism are opposing activities in organismic economy. And concordance of the correlation data with all the other is evidence the consistency procedure may yield reliable indices of inter-activity as well as inter-structure relations in colony populations.

These several explorations were planned as a coordinated attempt to get information on how colony integration is effected, and as experimental tests of a concept of growth (Hammett, 1936). That they all give the same answer is gratifying. The outcome shows the value of diverse approaches to a problem. And gives experimental backing to the contention that growth and living are compounded of integrated directional, chemical, physical, and morphological attributes (Hammett, 1938: 1941: 1942b: 1943b: 1944).

It would be strange if no seeming inconsistency reared its threatening head. One does. It is the correlation trend of the denominators of growth with the seniles. One would expect the trend to be negative, since the seniles are a denominator of dissolution, and the buds, halves, and three-quarters are negatively correlated with the other denominators of dissolution, viz. the empties and brokens. Instead it tends to be positive. Such is the trend expressed in 12 of the 18 possibilities. No trend is shown in 4: negative in 2. It is the trend exhibited—though unequally—by all 3. How does it happen that the denominators of growth are negatively correlated with the empties and brokens, but positively with the seniles?

Any answer based on these data alone would be inferential. So refuge is taken for the present in a fact and a possibility. The fact is that—"Whenever a correlation is observed, or a correlation coefficient is computed, let it be remembered first, last, and all the time, that it measures nothing and means nothing, except statistical association between the variables, no matter how glamorous or how seductive the suggestion as to causal relationship may seem to be. Correlation measures statistical association, not causation" (Pearl, 1940). This must be determined from other sources.

The possibility is that other sources of information which later will be available may make explanation less of a hung verdict. Such sources as the inter-structural relations in hydranth progression from initiation to subsequent states. Or information derived from data on the becomings of states: as distinct from data on the beings of states. Such as are here dealt with.

To sum up the over-all picture: The coefficients of correlation give quantitative exposition that—

1. An Obelia colony population is a compound of inter-related hydranth structures, within which are inter-related groups of specifically intra-related structures.

2. The buds, halves, and three-quarters comprise a group within which association is specifically conjunctive, or cooperant: the seniles, empties, and brokens comprise another.

3. The association between the 2 groups is disjunctive, or antagonistic: and both are disjunctively associated, or antagonistic with the completes.

4. Colony composition is thus the resultant of relations between individual structures, and of balance between groups of structures.

Since the buds, halves, and three-quarters are denominators of growth: the seniles, empties, and brokens of dissolution: and the completes of maintenance, the coefficients give quantitative exposition of the postulates that:

5. Colony composition is the resultant of balance between the growth, maintenance, and dissolution of its component hydranths.

6. The colony is primarily a colony of mature feeding animals to the establishment and continuance of which all growth and dissolution activities are tuned.

7. Maintenance is primary in organismic economy.

8. In Obelia colonies as elsewhere constructive substance increase or anabolism is opposed to or by destructive substance decrease or catabolism.

9. Growth and living are compounded of integrated directional, chemical, physical, and morphological attributes.

It is data such as these which seed crystallization of fact from the murk of inference. And raise concept of how growth is managed from guessing towards knowing.

This is as good a place as any to call first attention to how the behavior of the various members of the human family towards each other follows the pattern of the statistical associations of the hydranth members of the Obelia family.

Clearly the father and mother in a human family are the counterparts of the completes of an Obelia family. Both are the centers of family life: the providers: the mainstay of family existence.

Clearly the children of a human family are the counterparts of the buds, halves, and three-quarters of an Obelia family. Both constitute the immature components of the family group.

The maiden aunt of a human family has her similacrum in the seniles.

And the decrepit oldsters of a family of humans are similars of the empty and broken hydranths. Both have done their work.

As the buds, halves, and three-quarters of the Obelia family are statistically conjunctive among themselves as a group: so do the children of a human family club together in associative interests and activities. And as the buds, halves, and three-quarters are statistically

opposed to or by the completes: so is there antagonism between the self-expression of the children and parents.

As the empties and brokens of the Obelia family are statistically conjunctive as a group, and opposed to or by the completes: so do the oldsters of a human family unite in grumbling against the providers, while these in turn complain of the difficult old folks.

As the immature members of the Obelia family are statistically opposed to or by the empties and brokens: so do the children of a human family avoid the pernicketiness of the aged members, while these pick on the exuberance of the young.

And as the seniles tend to be cooperantly associated with the buds, halves, and three-quarters as one group, and the empties and brokens as another, while they are opposed to or by the completes: so does the maiden aunt act in opposition to the parents, and take the part of the children on the one hand, and of the oldsters on the other, in their conflicts with each other and with the head of the family.

The concordance of these generally exhibited behavioristic alliances and antagonisms within a family of humans with the purely statistical associations of hydranth states in the Obelia family, is amusing and intriguing. Could it possibly be that we are considerably the subjects of our cellular activities and relations as suggested elsewhere (Hammett, 1936): and that our much-vaunted free will is not as free as it might be?

Communal vs. *Intrinsic Relations:* The foregoing is quantitative exposition that the 7 definitive hydranth states comprising an Obelia colony population constitute an integrated family of inter-related structures.

It has already been noted that 2 expressions of statistical association are had. One is the Intrinsic association. Or the association which 2 structures have for each other free from interference from other members of the family of structures. This is given by the 5th Order data. The other is the Communal association. Or the association which 2 structures express when subject to influence from the other members of the family. This is given by the Zero Order data and supplemented by those of table 8.

Naturally we want to know, (1) If the communal association of any given coupling differs from the intrinsic. i.e. If the inherent association between 2 structures is modified by colony influence. (2) The

nature of the difference if such exists. i.e. Whether the association is strengthened or weakened. And (3) If inherent association is modified by colony influence what structure or structures are responsible for the modification.

Two sets of data are available for estimate. (1) Communal association difference from intrinsic in intensity of correlation. (2) Communal association difference from intrinsic in frequency with which statistically valid correlation is expressed.

1. Difference in intensity has 3 indices with 6 expressions. (a) Frequency with which the statistically valid Zero Order coefficients of each coupling are greater, less, and no different than the 5th Order. (b) Direction of deviation of the average value of the statistically valid Zero Order coefficients from that of their homologous 5th Order coefficients. i.e. Zero Order coefficients may average higher, lower, or the same as the 5th Order. (c) Direction of deviation in distribution of the components of the Zero Order average from that of the homologous 5th Order.

Tables 6 and 7 show that the statistically valid correlation expressed by most couplings tends to be either towards conjunctivity or disconjunctivity. When it is conjunctive—only the positive correlation coefficient are used. When it is disjunctive—only the negative.

a. The frequency with which the stated Zero Order coefficients of each coupling are greater, less, and no different than the 5th is gotten as follows.

All the statistically valid coefficients of the trend which dominates the association are taken from tables 3 and 4. These are lined up against their 5th and Zero Order homologs. Then the number of times Zero Order is greater, less, and no different than 5th is gotten. For the *Sr*- and *PE*-valid data separately. The results are given for each coupling in table 9. From this it is seen that the buds-halves coefficients are greater than the 5th Order more frequently than less. Which shows that communal association here is greater more frequently than less. Which means that expression of buds-halves association tends to be strengthened by colony influence. Such is the estimate recorded under the Zero vs. 5th Order heading. And so on similarly.

b. The next data in the intensity set are the average values of the Zero and 5th Order coefficients. These, as gotten by usual pro-

TABLE 9

COMMUNAL ASSOCIATION DIFFERENCE FROM INTRINSIC IN INTENSITY OF CORRELATION

A. Frequency with Which *Sr*- and *PE*-Valid Coefficients Are Greater, Less, and No Different Than the 5th Order

Couple	r_{xy}	+	−	=	Zero vs. 5th	*Couple*	r_{xy}	+	−	=	Zero vs. 5th
Buds-½s	*Sr*	4	2	2	More	¾s-Comps.	*Sr*	3	9	0	Less
	PE	7	2	2	More		*PE*	3	12	0	Less
Buds-¾s	*Sr*	8	0	1	More	¾s-Senls.	*Sr*	1	1	1	Same
	PE	14	0	3	More		*PE*	2	3	1	Same
Buds-Comps.	*Sr*	3	6	2	Less	¾s-Empts.	*Sr*	2	1	0	More
	PE	3	7	3	Less		*PE*	6	1	0	More
Buds-Senls.	*Sr*	2	1	0	More	¾s-Brokns.	*Sr*	7	3	1	More
	PE	5	3	0	More		*PE*	8	7	4	Same
Buds-Empts.	*Sr*	5	4	2	Equal	Comps.-Senls.	*Sr*	10	2	2	More
	PE	5	4	2	Equal		*PE*	11	3	3	More
Buds-Brokns.	*Sr*	8	11	5	Less	Comps.-Empts.	*Sr*	10	1	2	More
	PE	11	12	5	Same		*PE*	11	4	3	More
½s-¾s	*Sr*	2	2	0	Same	Comps.-Brokns.	*Sr*	10	4	1	More
	PE	6	3	0	More		*PE*	12	5	1	More
½s-Comps.	*Sr*	3	6	1	Less	Senls.-Empts.	*Sr*	11	1	0	More
	PE	4	6	1	Less		*PE*	15	1	0	More
½s-Senls.	*Sr*	4	0	0	More	Senls.-Brokns.	*Sr*	8	1	0	More
	PE	6	2	0	More		*PE*	12	4	0	More
½s-Empts.	*Sr*	1	3	0	Less	Empts.-Brokns.	*Sr*	12	1	0	More
	PE	1	5	0	Less		*PE*	19	1	0	More
½s-Brokns.	*Sr*	3	2	0	Same						
	PE	7	5	1	More						

cedure, are given for each coupling, in table 10. For the *Sr*- and *PE-valid* data separately.

Each vertical column of each series gives the average values of the coefficients of correlation of the structure designated at the head of the column with each of the other structures in the order of the life-cycle progression. As indicated at the left. Thus—under Buds is given successively the average magnitude of bud correlation with halves (H); three-quarters (T); completes (C); seniles (S); empties (E); and brokens (b). And so on similarly.

The number of *Sr*-valid positive coefficients is the same as the negative in the Zero Order buds-seniles, and three-quarters-empties couplings. And the same is true in the 5th Order three-quarter seniles and three-quarter-empties couplings. Correlative data suggest the trends to be respectively positive, negative, positive, negative in the 4 cases. So these are used for the respective averages. No *Sr*-valid coefficients are had in the 5th Order halves-seniles coupling. But the *PE*-valid hint of a trend to positive correlation. So here the positive coefficients

TABLE 10

COMMUNAL ASSOCIATION DIFFERENCE FROM INTRINSIC IN INTENSITY OF CORRELATION
B. The Average Value of the *Sr* and *PE* Significant Coefficients of Correlation of Each of the 21 Pairs of Variables

Buds		Halves		¾s		Compls		Senils		Empts		Brokns	
						Zero Order Sr							
H	+.307	B	+.307	B	+.398	B	—.412	B	+.345	B	—.337	B	—.411
T	+.398	T	+.258	H	+.258	H	—.357	H	+.294	H	—.261	H	—.329
C	—.412	C	—.357	C	—.362	T	—.362	T	+.349	T	—.323	T	—.335
S	+.345	S	+.299	S	+.349	S	—.427	C	—.427	C	—.350	C	—.342
E	—.337	E	—.261	E	—.323	E	—.350	E	+.362	S	+.362	S	+.399
b	—.411	b	—.329	b	—.335	b	—.342	b	+.399	b	+.382	E	+.382
						Zero Order PE							
H	+.290	B	+.290	B	+.312	B	—.375	B	+.280	B	—.317	B	—.389
T	+.312	T	+.262	H	+.262	H	—.320	H	+.258	H	—.231	H	—.274
C	—.375	C	—.320	C	—.329	T	—.329	T	+.306	T	+.258	T	—.324
S	+.280	S	+.258	S	+.306	S	—.401	C	—.401	C	—.322	C	—.334
E	—.317	E	—.231	E	+.258	E	—.322	E	+.330	S	+.330	S	+.342
b	—.389	b	—.274	b	—.324	b	—.334	b	+.342	b	+.323	E	+.323
						5th Order Sr							
H	+.334	B	+.334	B	+.350	B	—.378	B	+.367	B	—.308	B	—.404
T	+.390	T	+.289	H	+.289	H	—.338	H	+.253	H	—.340	H	—.333
C	—.378	C	—.338	C	—.339	T	—.339	T	+.419	T	—.313	T	—.351
S	+.316	S	+.253	S	+.419	S	—.367	C	—.367	C	—.345	C	—.337
E	—.308	E	—.340	E	—.313	E	—.345	E	+.289	S	+.289	S	+.359
b	—.404	b	—.333	b	—.351	b	—.337	b	+.359	b	+.328	E	+.328
						5th Order PE							
H	+.296	B	+.296	B	+.359	B	—.352	B	+.295	B	—.286	B	—.388
T	+.359	T	—.258	H	—.258	H	—.330	H	+.225	H	—.279	H	—.255
C	—.352	C	—.330	C	—.310	T	—.310	T	+.309	T	—.243	T	—.302
S	+.295	S	+.225	S	+.309	S	—.340	C	—.340	C	—.289	C	—.311
E	—.286	E	—.279	E	—.243	E	—.289	E	+.257	S	+.257	S	+.323
b	—.388	b	—.255	b	—.302	b	—.311	b	+.323	b	+.283	E	+.283

B—Buds: H—Halves: T—Three-Quarters: C—Completes: S—Seniles: E—Empties: b—Brokens

are used for the *Sr*-average. If these adjustments seem too nonchalant, let the reader do his own juggling. The over-all picture will not be changed.

The direction of deviation of Zero from the 5th Order is easy to get. Thus—buds-halves *Sr*-valid Zero Order average is +.307, and 5th Order is +.334. This shows the average value of the Zero Order buds-halves coefficients is less than the 5th Order on this basis. And so on similarly.

The direction of difference between homologus average is given in table 12. Which summarizes all the data for each coupling. Evaluation will be made when these are analyzed.

c. The final item of intensity data is comprised in the record of

distribution of the components of the averages. Tables 6 and 7 show the number of coefficients going into the averages is quite small in some cases, and varies greatly from coupling to coupling. So estimate of differences between averages is on shaky foundation. And anyhow averages of coefficients of correlation are not so hot statistically. In such material evaluation of differences by Standard Deviation is futile. So, in order to have some correlative information a rough measure of differences in distribution of the components of the averages has been attempted. Chi Square data would be meaningless. So the following procedure has been employed.

Using the Zero Order *Sr* coefficients of table 3 as example the largest is 0.697: the smallest 0.221. This gives 17 classes with a class range of 0.03. And such is scaled off as on the sample chart 1: start-

CHART 1

COMMUNAL ASSOCIATION DIFFERENCE FROM INTRINSIC IN INTENSITY OF CORRELATION

Ca. Sample Distribution of Correlation Coefficients

(Zero Order *Sr* Values for Buds-Halves and Buds-Three-Quarters Associations)

r_{xy}	68 70	65 67	62 64	59 61	56 58	53 55	50 52	47 49	44 46	41 43	38 40	35 37	32 34	29 31	26 28	23 25	20 22	Av. r_{xy}
B H														x	x			0.307
7										x			x	x	x	x		
B T										x								
9									x	x								0.398
								x	x	x		x		x	x			

Quartered Per Cent Distribution (Cf. Table 11)

	1	2	3	4	
B H	0.0	0.0	14.3	85.7	0.307
B T	0.0	11.1	66.7	22.2	0.398

ing with 0.70 and ending with 0.20. The scale is quartered to best approximation. Then the coefficients of each coupling are distributed along the scale. As shown for the buds-halves and buds-three-quarters separately. The percentage distribution of the coefficients among the 4 sections is computed for each coupling. It is set down as seen on the chart. And so on similarly. The results of this procedure are given in table 11. For the Zero Order *Sr*: Zero Order *PE*: 5th Order *Sr*: and 5th Order *PE* data of each coupling separately. In a few cases all the coefficients fall in the lowest quarter-section. Here the

TABLE 11

COMMUNAL ASSOCIATION DIFFERENCE FROM INTRINSIC IN INTENSITY OF ASSOCIATION

C. The Quartered Per Cent Distribution of the *Sr* and *PE* Valid Coefficients of Correlation

r_{ay}	1	2	3	4	1	2	3	4
			Sr		Zero Order		*PE*	
BH	0.0	0.0	14.3	85.7	0.0	0.0	45.5	54.5
BT	0.0	11.1	66.7	22.2	0.0	29.4	29.4	41.2
BC	14.3	14.3	28.6	42.9	11.1	11.1	66.7	11.1
BS	0.0	0.0	66.7	33.3	0.0	0.0	33.3	66.7
BE	0.0	14.3	28.6	57.1	0.0	22.2	11.1	66.7
Bb	8.7	17.4	39.1	34.8	7.4	18.5	51.9	22.2
HT	0.0	0.0	0.0	100.0	0.0	0.0	16.7	83.3
HC	0.0	0.0	50.0	50.0	0.0	0.0	80.0	20.0
HS	0.0	0.0	0.0	100.0	0.0	0.0	37.5	62.5
HE	0.0	0.0	0.0	100.0	0.0	0.0	16.7	83.3
Hb	0.0	0.0	25.0	75.0	0.0	0.0	44.4	55.6
TC	0.0	12.5	50.0	37.5	0.0	10.0	60.0	30.0
TS	0.0	0.0	33.3	66.7	0.0	0.0	75.0	25.0
TE	0.0	0.0	0.0	100.0	0.0	0.0	33.3	66.7
Tb	0.0	0.0	36.4	63.6	0.0	0.0	80.0	20.0
CS	0.0	23.1	61.5	15.4	6.7	40.0	40.0	13.3
CE	0.0	7.7	46.1	46.1	0.0	12.5	43.7	43.7
Cb	7.1	0.0	28.6	64.3	6.3	6.3	56.2	31.2
SE	9.1	0.0	45.5	45.5	6.7	6.7	40.0	46.6
Sb	25.0	12.5	12.5	50.0	15.4	7.7	30.8	46.1
Eb	0.0	16.7	33.3	50.0	5.3	10.5	42.1	42.1
			Sr		5th Order		*PE*	
BH	0.0	0.0	20.0	80.0	0.0	14.3	28.6	57.1
BT	0.0	0.0	71.5	28.6	0.0	11.1	66.7	22.2
BC	0.0	10.0	50.0	40.0	0.0	7.7	38.5	53.8
BS	0.0	0.0	0.0	100.0	0.0	0.0	80.0	20.0
BE	0.0	0.0	14.3	85.7	0.0	0.0	45.4	54.6
Bb	4.5	13.6	40.9	40.9	4.0	24.0	44.0	28.0
HT	0.0	0.0	0.0	100.0	0.0	0.0	22.2	77.8
HC	0.0	10.0	10.0	80.0	0.0	9.1	54.5	36.4
HS	0.0	0.0	0.0	100.0	0.0	0.0	0.0	100.0
HE	0.0	0.0	33.3	66.7	0.0	0.0	33.3	66.7
Hb	0.0	0.0	33.3	66.7	0.0	0.0	11.1	88.9
TC	0.0	9.1	27.3	63.6	0.0	6.7	26.7	66.7
TS	0.0	0.0	50.0	50.0	0.0	20.0	20.0	60.0
TE	0.0	0.0	0.0	100.0	0.0	0.0	33.3	66.7
Tb	0.0	0.0	25.0	75.0	0.0	6.2	37.5	56.3
CS	0.0	9.1	27.3	63.6	0.0	13.3	40.0	46.7
CE	0.0	0.0	28.6	71.5	0.0	15.4	15.4	69.2
Cb	0.0	10.0	10.0	80.0	0.0	6.7	33.3	60.0
SE	0.0	0.0	0.0	100.0	0.0	0.0	12.5	87.5
Sb	0.0	0.0	40.0	60.0	0.0	10.0	40.0	50.0
Eb	0.0	0.0	16.7	83.3	0.0	10.0	10.0	80.0

TABLE 11a

COMMUNAL ASSOCIATION DIFFERENCE FROM INTRINSIC IN INTENSITY OF ASSOCIATION

C. The Per Cent Distribution of the Coefficients of Correlation in the Halved 4th Quarter-Section

	4a Zero Order	4b *tr*		4a 5th Order	4b *tr*		4a 5th Order	4b *PE*
HT	0.0	100.0	BS	100.0	0.0	HS	50.0	50.0
HS	50.0	50.0	HT	50.0	50.0			
HE	50.0	50.0	HS	0.0	100.0			
TE	100.0	0.0	TE	100.0	0.0			
			SE	60.0	40.0			

TABLE 12

TREND OF DIFFERENCE BETWEEN COMMUNAL AND INTRINSIC ASSOCIATION OF HYDRANTH STRUCTURAL STATES IN OBELIA COLONY POPULATIONS.

Zero Order r_{xy} vs. 5th Order r_{xy}

	Zero vs. 5th Trend			Intensity (Tables 9, 10, 11, 11a) Δf		Av.		Dstb.		Frequency (Tables 6:7) *Net* *Sr*			*PE*			*Gross* *Sr*			*PE*		
Pairs	IN	FR	OA	*S*	*P*	*S*	*P*	*S*	*P*	A	M′	Y	A	M′	Y	A	M′	Y	A	M′	Y
BH	M	M	*M*	+	+	−	=	=	−	+	=	+	+	+	+	+	=	=	+	+	+
BT	M	M	*M*	+	+	=	−	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BC	L	L	*L*	−	−	+	+	+	+	−	−	=	−	−	−	−	−	+	−	−	−
BS	M	L	*D*	+	+	+	−	+	−	=	−	=	+	−	+	−	−	=	=	−	=
BE	M	L	*D*	=	=	+	+	+	+	=	+	−	=	=	−	−	+	−	−	−	−
Bb	L	L	*L*	−	=	=	=	=	=	=	−	=	+	−	=	=	−	=	=	−	=
HT	M	M	*M*	=	+	−	=	−	=	=	=	=	−	−	=	+	+	+	−	−	+
HC	L	L	*L*	−	−	+	=	+	+	−	−	−	−	−	=	−	−	−	−	=	−
HS	M	M	*M*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
HE	L	L	*L*	−	−	−	−	−	−	−	−	+	=	+	−	−	−	=	+	+	=
Hb	M	M	*M*	=	+	=	+	=	+	+	+	=	=	−	=	+	+	=	−	−	=
TC	L	L	*L*	−	−	+	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−
TS	S	M	*M*	=	=	−	=	=	+	+	=	+	−	+	+	+	+	+	+	+	+
TE	S	M	*M*	=	=	=	+	=	=	=	=	=	+	+	+	=	=	=	+	=	=
Tb	M	S	*M*	+	=	=	+	=	+	+	=	=	−	−	=	+	=	=	−	−	=
CS	M	M	*M*	+	+	+	+	+	+	+	−	=	+	−	=	+	−	+	=	+	=
CE	M	M	*M*	+	+	=	+	+	+	+	−	+	+	−	=	+	−	+	+	−	=
Cb	M	M	*M*	+	+	=	+	+	+	+	+	+	+	+	=	+	+	+	=	+	=
SE	M	M	*M*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Sb	M	M	*M*	+	+	+	+	+	+	+	+	+	+	=	+	+	+	+	+	=	+
Eb	M	M	*M*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

IN—Intensity: FR—Frequency: OA—Overall: *S*—*Sr*: *P*—*PE*: A—All: M′—Month: Y—Year: M—More: L—Less: D—Different: S—Same.

distribution is gotten by halving the section scale and computing the percentage of coefficients in each. The results are given in table 11a.

These data supplement the averages. Thus—table 10 shows the average value of the 7 buds-halves coefficients is 0.307: and that of the buds-three-quarters is 0.398. But the difference cannot be vali-

dated by standard statistical procedure. The quartered percent distributions show that the buds-halves coefficients fall more frequently in lower sections than do the buds-three-quarters: and less frequently in the higher. The difference in distribution of the buds-halves coefficients from those of the buds-three-quarters is the same in direction as the difference between the averages. The 2 data are consistent. They thus give likelihood that buds-halves association is really less in intensity than buds-three-quarters. It's a guess of course. But "Some progress is made on stilts" (Joyce, 1939). And so on similarly.

Table 12 gives the direction of difference in distribution of Zero and 5th Order homologous coefficients. For each coupling. For the *Sr*- and *PE*-valid coefficients separately. Evaluation will be made in its proper place. So much for the intensity data. Now for the frequency.

2. Difference in frequency with which statistically valid correlation is expressed by the Zero Order and 5th Order homologous couplings has 2 indices, 3 sub-indices, and 12 expressions. (a) Zero Order difference from 5th in *gross* frequency of positive correlation when this dominates: of negative when this dominates: in the ALL, Month, and Year brackets separately. For the *Sr*-and *PE*-valid coefficients separately. (b) Zero Order difference from 5th in *net* frequency of positive correlation when this dominates: of negative when this is ascendent: in the ALL, Month, and Year brackets separately. For the *Sr*- and *PE*-valid coefficients separately.

a. Gross frequency is the number of valid coefficients of greater occurrence. e.g. The gross frequency of Zero Order buds-halves association is 7 (table 6: ALL: *Sr*-valid): and of 5th Order is 5 (table 7). Clearly the frequency of valid Zero Order correlation expression is greater than 5th. By more than 5 per cent. Which means that communal capacity of the buds to associate with the halves is greater than the intrinsic. Which indicates that communal association is here increased by colony influence. And such is recorded by a *plus* under GROSS: *Sr*: ALL, in table 12. And so on similarly for the Month and Year data: and the *Sr*- and *PE*-valid data of each coupling.

b. *Net* frequency is the difference between gross and that of the correlation of opposite sign. e.g. In the cited example Zero Order net frequency is 7 minus 1, or 6. And 5th Order is 5 minus 0, or 5. The frequency of valid Zero Order net correlation is greater than 5th

by more than 5 per cent. And such is recorded under NET: *Sr*: ALL, in table 12. And so on similarly as above.

Thus 12 expressions of frequency difference between Zero and 5th Order association are had. These, plus the 6 expressions of intensity difference give a total of 18 for each coupling. From which decision as to trend of Zero Order difference from 5th is obtained.

Nobody would expect anybody to make estimate of communal association difference from intrinsic from the scattered data of tables 6, 7, 9, 10, 11, and 11a as such. So table 12 has been prepared. In this all expressions of difference are assembled and summarized. Separate estimate is given for the intensity (IN), frequency (FR), and over-all (OA) differentials. Under the Zero vs. 5th Order TREND heading. Communal association superiority to intrinsic is marked by M (more): inferiority by L (less): equality by S (same): oppositeness by O.

Differences in *Sr* data are more reliable indices than differences in *PE*. So they are given first rank in getting estimate. When equality in *Sr* is shown, the *PE* trend is used.

The relative concordance of the 3 intensity indices with the frequency is index to their relative reliability. The table shows that, (a) The consistency differential (Δf) is the same as the frequency (FR) in 16 of the 17 feasible comparisons. (b) The distribution (Dstb.) is the same in 11, and opposite in 6. And (c) The average (Av.) is the same in 10 of the feasible comparisons, and opposite in 8. The conclusion must be that the consistency is the most reliable: the distribution the next: and the average a very weak third. So in making the intensity estimate the consistency data are given first rank. If the distribution and the average differentials check therewith, so much the better. But if they don't decision is based on the consistency data. When equality is shown in these and a trend in the others, such is used for the estimate (buds-empties).

In the frequency data, the net differential is obviously a better index than the gross: the ALL than the Year: and the Year than the Month. So this is the order of weight given to these items in making estimate of the frequency differential. So much for all this. Now to see what the table tells of communal association deviation from intrinsic.

It could *a priori* be expected that difference in capacity to associate

and difference in intensity of association would be positively correlated. The table shows that the direction of Zero Order difference from 5th in intensity is the same as the frequency in 16 of the 21 couplings: opposite in 2: and uncomparable in 3 (because no difference is expressed in either intensity or frequency). Concordance is had in 89 per cent of the feasible comparisons. Since fact coincides with fancy it may be assumed that the estimates of communal-intrinsic association differentials are reasonably valid indices to true relations. It also indicates the procedures are not ill-managed. Continuing—

The table shows that, (a) Communal association is greater than intrinsic in intensity in 14 of the 21 couplings: less in 5: equal in 2. (b) Communal association is greater than intrinsic in frequency of correlation expression in 13 of the 21 couplings: less in 7: equal in 1. And, (c) Communal association is greater than intrinsic in the overall picture in 14 of the 21 couplings: less in 5: and not comparable in 2. The whole shows that, (a) Communal association is quite generally different from intrinsic. And, (b) Communal association is greater than intrinsic in most couplings. Which means that, (a) Expression of association is quite generally modified by colony influence. And, (b) Most expressions of association are strengthened by colony influence.

These things being so, knowledge is wanted of which structure or structures are responsible for the differences. This means getting record of how each given coupling is affected by each other structure. Or how, for instance, the buds-halves intrinsic association is modified by the three-quarters, the completes, the seniles, the empties, and the brokens separately. This is done by getting the direction of deviation of 4th Order coefficients from their 5th Order homologs. A 4th Order coefficient gives the association between 2 structures when all but one of the other structures is held constant. So a 4th Order coefficient gives the association which 2 structures express when subject to the influence of *one* of the other structures. If a 4th Order coefficient is larger than its 5th Order homolog, the structure not held constant factors an increase in association. If a 4th Order coefficient is smaller, then the structure not held constant conditions a decrease. e.g. Table 13 shows a buds-halves 5th Order coefficient of 0.470. Its 4th Order homolog with brokens running

TABLE 13

DIFFERENCE BETWEEN ZERO AND 5TH ORDER, AND 4TH AND 5TH ORDER CORRELATION COEFFICIENTS OF THE BUDS-HALVES ASSOCIATIONS (N=11)
(*PE*-valid coefficients: which include the *Sr*-valid)

Zero BH	5th BH		¾		Compl.		4th Order Senl.		Empt.		Brkn.	
r_{xy}	r_{xy}	Δ	r_{xy}	Δ	r_{xy}	Δ	r_{xy}	Δ	r_{xy}	Δ	r_{xy}	Δ
+.211	+.183	+	+.243	+	+.143	−	+.165	−	+.182	=	+.145	−
+.390	−.169	+	−.061	−	+.393	+	−.199	+	−.171	=	−.214	+
+.263	+.237	+	+.244	=	+.267	+	+.215	−	+.240	=	+.239	=
+.300	+.288	=	+.305	+	+.273	−	+.231	=	+.296	=	+.298	=
+.303	+.316	=	+.311	=	+.331	=	+.316	=	+.248	−	+.321	=
+.428	+.470	−	+.431	−	+.462	=	+.469	=	+.409	−	+.507	+
+.250	+.112	+	+.146	+	+.115	=	+.127	+	+.091	−	+.182	+
+.192	+.037	+	+.057	=	+.117	+	+.108	+	+.095	=	+.167	+
+.265	+.198	+	+.193	=	+.141	−	+.208	+	+.172	−	+.299	+
+.245	+.357	−	+.245	−	+.320	−	+.335	−	+.362	=	+.345	=
+.342	+.203	+	+.199	=	+.404	+	+.229	+	+.194	=	+.174	−
	+	− =	+	− =	+	− =	+	− =	+	− =	+	− =
Frequency Δ	7	2 2	3	3 5	4	4 3	5	3 3	0	4 7	5	2 4

wild is 0.507. So in this particular case buds-halves association is greater when subject to the influence of the brokens. Which means that the brokens are a factor of increase in buds-halves association. And so on similarly.

The base data for this analysis are the same *PE*-valid coefficients as those used for the consistency of communal association difference from intrinsic in intensity (table 9). The *PE*-valid coefficients—which include the *Sr*-valid—are used with 2 exceptions. First, because they show the same direction of difference as the *Sr*, only more so in most cases. And second, because this increases the number of comparisons (table 9). In the case of the halves-brokens and the three-quarter brokens series only the *Sr*-valid coefficients are used. This is because the trend is less clean-cut when the non-*Sr*-valid coefficients are added (table 9).

The procedure is illuminated by table 13. The pertinent Zero Order coefficients are lined up in the 1st column against their 5th Order homologs in the 2nd. The direction of deviation of each Zero Order value from its 5th Order homolog is marked to the right, and summed at the bottom. The 4th Order homologs with the three-quarters unstabilized are lined up in the 3rd column. The direction of deviation of each from its 5th Order homolog is marked at the right, and

TABLE 14

FREQUENCY IN DIRECTION OF DIFFERENCE OF ZERO ORDER COEFFICIENTS FROM 5TH ORDER (BH: BT: BC: ETC. ROWS). AND FREQUENCY IN DIRECTION OF DIFFERENCE OF 4TH ORDER COEFFICIENTS FROM 5TH ORDER (T: C: S: ETC. ROWS). (*PE*-valid coefficients: which include the *tr*-valid).

	BH				BT				BC				BS				BE				Bb				HT			
11	+	−	=	Tr	17	+	−	=	Tr	13	+	−	=	Tr	8	+	−	=	Tr	11	+	−	=	Tr	24	+	−	=	Tr	9	+	−	=	Tr
BH	*7*	*2*	*2*	+	*BT*	*14*	*0*	*3*	+	*BC*	*3*	*7*	*3*	−	*BS*	*5*	*3*	*0*	+	*BE*	*5*	*4*	*2*	=	*Bb*	*8*	*11*	*5*	−	*HT*	*6*	*3*	*0*	+
T	3	3	5	=	H	5	4	8	=	H	1	6	6	−	H	1	1	6	=	H	2	6	3	−	H	3	5	16	−	B	2	4	3	−
C	4	4	3	=	C	11	2	4	+	T	7	5	1	+	T	*2*	*2*	4	=	T	2	5	4	−	T	6	4	14	+	C	3	4	2	=
S	5	3	3	+	S	7	2	8	+	S	5	2	6	+	C	3	1	4	+	C	0	7	4	−	C	6	10	8	−	S	3	2	4	=
E	0	4	7	−	E	4	6	7	−	E	2	5	6	−	E	4	1	3	+	S	3	1	7	+	S	6	5	13	=	E	3	1	5	+
b	5	2	4	+	b	10	2	5	+	b	3	8	2	−	b	3	3	2	=	b	9	0	2	+	E	8	1	15	+	b	4	1	4	+

	HC				HS				HE				Hb				TC				TS				TE			
11	+	−	=	Tr	8	+	−	=	Tr	6	+	−	=	Tr	13	+	−	=	Tr	15	+	−	=	Tr	6	+	−	=	Tr	7	+	−	=	Tr
HC	*4*	*6*	*1*	−	*HS*	*6*	*2*	*0*	+	*HE*	*1*	*5*	*0*	−	*Hb*	*7*	*5*	*1*	+	*TC*	*3*	*12*	*0*	−	*TS*	*2*	*3*	*1*	=	*TE*	*6*	*1*	*0*	+
B	1	5	5	−	B	4	1	3	+	B	0	2	4	−	B	5	4	4	=	B	3	5	7	−	B	1	1	4	=	B	2	4	1	−
T	3	5	3	−	T	4	0	4	+	T	3	1	2	+	T	6	2	5	+	H	3	6	6	−	H	2	1	3	=	H	1	1	5	=
S	3	2	6	=	C	4	3	1	=	C	0	2	4	−	C	6	4	3	+	S	3	4	8	=	C	1	4	1	−	C	3	1	3	+
E	2	2	7	=	E	5	0	3	+	S	0	2	4	−	S	3	5	5	−	E	5	2	8	+	E	1	1	4	=	S	4	0	3	+
b	1	3	7	−	b	4	2	2	+	b	1	0	5	=	E	2	6	5	−	b	0	8	7	−	b	2	3	1	=	b	2	2	3	=

	Tb				CS				CE				Cb				SE				Sb				Eb			
11	+	−	=	Tr	17	+	−	=	Tr	18	+	−	=	Tr	18	+	−	=	Tr	16	+	−	=	Tr	16	+	−	=	Tr	20	+	−	=	Tr
Tb	*6*	*3*	*2*	+	*CS*	*11*	*3*	*3*	+	*CE*	*11*	*4*	*3*	+	*Cb*	*12*	*5*	*1*	+	*SE*	*15*	*1*	*0*	+	*Sb*	*12*	*4*	*0*	+	*Eb*	*19*	*1*	*0*	+
B	5	3	3	+	B	9	4	4	+	B	4	5	9	=	B	5	7	6	−	B	9	3	4	+	B	6	6	4	=	B	13	2	5	+
H	5	2	4	+	H	5	2	10	+	H	6	4	8	+	H	5	7	6	−	H	4	6	6	−	H	4	4	8	=	H	3	7	10	−
C	3	7	1	−	T	4	4	9	=	T	5	4	9	=	T	3	10	6	−	T	6	1	9	+	T	4	5	7	=	T	5	5	10	=
S	2	1	8	=	E	10	1	6	+	S	10	2	6	+	S	7	1	10	+	C	8	1	7	+	C	5	3	8	+	C	13	1	6	+
E	3	0	8	+	b	7	2	8	+	b	15	1	2	+	E	11	1	6	+	b	11	1	4	+	E	10	1	5	+	S	14	1	5	+

summed at the bottom. And so on similarly. The 3rd column gives the associations expressed by the buds with the halves when subject to influence of the three-quarters. The 4th gives that expressed under the influence of the completes. And so on similarly. The frequency with which the 3rd column 4th Order coefficients are greater, less, and no different from 5th is index to how buds-halves association is influenced by the three-quarters. And so on similarly. It happens in this case that 4th Order coefficients were greater and less than 5th with equal frequency (bottom 3rd column). So no evidence is had that buds-halves association is modified in one direction by the three-quarters.

By this procedure record is gotten of how the association of each coupling is modified by each other structure. The data are given in table 14. This is used as follows. The Zero Order buds-three-quarters coefficients (BT) are greater than their 5th Order homologs in 14 of the 17 comparisons: less in none: equal in 3. Communal association here is greater than intrinsic. The 4th Order coefficients with the completes unstabilized (C) are greater than the 5th in 11 of the 17 comparisons: less in 2: equal in 4. This shows the completes condition an increase in expression of buds-three-quarters association. Which means that the greater communal association is here in part attributable to influence of the completes. And so on similarly.

These are statistical relations. Interpretation will now be given for each of the 21 couplings. While "The situation is complicated and its difficulties enhanced by the impossibility of saying everything at once" (Woodger: quoted by Brody, 1945), the gist of the relations should be grasped by the reader without too much difficulty.

To save verbification and space the custom of repeating in the argument the numerical evidence of the table will be discontinued. Each can check statement against the record for himself. Table 14 shows that—

1. *Buds-Halves* association is increased by colony influence. The brokens and the seniles, in the order given, are fortifying factors: the empties weakening: the three-quarters and completes non-contributors.

This shows that the brokens and the seniles are the structures responsible for communal association difference from intrinsic. It means that the expression of buds-halves association within the

Obelia family of hydranth structures is dominantly conditioned by the brokens and seniles.

Precise statement of this in terms of activity would be: The expression of association between the denominator of initiation and the denominator of proliferation within the colony activity field is dominantly factored by the denominator of injury and the denominator of regression. This is cumbersome. So, with the understanding we are dealing with relations between product-expressions of activities, and not with relations between activities as such, transposition will be condensed into the following type of statement.

In activity terminology this finding means that expression of association between initiation and proliferation within the colony activity field is dominantly conditioned by injury and regression.

2. *Buds-Three-Quarters* association is increased by colony influence. The completes, seniles, and brokens are fortifying factors: the empties weakening: the halves non-contributors.

This shows that the completes, the seniles, and the brokens are the structures responsible for communal association difference from intrinsic. It means that expression of buds-three-quarters association within the colony set-up is mediated by the completes, seniles, and brokens.

In activity terminology it means that expression of association between initiation and differentiation within the colony activity field is dominantly conditioned by maintenance, regression, and injury.

3. *Buds-Completes* association is decreased by colony influence. The halves, brokens, and empties are reducing factors: the seniles and three-quarters strengthening.

This shows that the halves, the brokens, and the empties are the structures responsible for communal association difference from intrinsic. It means that expression of buds-completes association within colony populations is dominantly factored by the halves, brokens. and empties.

In activity terminology it means that expression of association between initiation and maintenance within the colony activity field is dominantly conditioned by proliferation, injury, and catabolism.

4. *Buds-Seniles* association tends to be increased by colony influence. The empties, and completes are fortifying factors: the halves, three-quarters, and brokens non-contributors.

This shows that the empties and the completes are the structures responsible for communal association difference from intrinsic. It means that the expression of buds-seniles association within the hydranth family of structures is dominantly mediated by the empties, and completes.

In activity terminology it means that expression of association between initiation and regression within the colony activity field is dominantly conditioned by catabolism and maintenance.

5. *Buds-Empties* communal association is the same as intrinsic. The brokens, and seniles are strengthening factors: the completes, halves, and three-quarters weakening.

This shows, not that buds-empties association within the colony set-up is unaffected by other structures; but that the fortifying influence of the brokens and the seniles is balanced and neutralized by the weakening influence of the completes, the halves, and the three-quarters.

In activity terminology it means that the strengthening influence of injury and regression on the expression of association between initiation and catabolism within the colony activity field is balanced by the weakening influence of maintenance, proliferation, and differentiation.

6. *Buds-Brokens* association tends to be decreased by colony influence. The halves, and completes are reducing factors: the empties and three-quarters fortifying: the seniles non-contributors.

This shows that the halves and the completes are the structures responsible for the communal association difference from intrinsic. It means that expression of buds-brokens association in colony populations is dominantly conditioned by the halves and completes.

In activity terminology it means that expression of association between initiation and injury within the colony activity field is dominantly conditioned by proliferation and maintenance.

7. *Halves-Three-Quarters* association is increased by colony influence. The brokens and empties are fortifying factors: the buds weakening: the completes and seniles non-contributors.

This shows that the brokens and the empties are the structures responsible for communal association difference from intrinsic. It means that expression of halves-three-quarters association within the colony set-up is dominantly conditioned by the brokens and empties.

In activity terminology it means that expression of association between proliferation and differentiation within the colony activity field is dominantly conditioned by injury and catabolism.

8. *Halves-Completes* association tends to be decreased by colony influence. The buds, brokens, and three-quarters are reducing factors: the seniles and empties non-contributors.

This shows that the buds, the brokens, and the three-quarters are the structures responsible for communal association difference from intrinsic. It means that the expression of halves-completes association within the hydranth family of structures is dominantly mediated by the buds, brokens, and three-quarters.

In activity terminology it means that expression of association between proliferation and maintenance within the colony activity field is factored by initiation, injury, and differentiation.

9. *Halves-Seniles* association is increased by colony influence. The empties, three-quarters, buds, and brokens are the fortifying factors. The completes are non-contributors.

This shows that all structures save the completes contribute to communal association difference from intrinsic in this case. It means that expression of halves-senile association in colony populations is factored by the empties, the three-quarters, the buds, and the brokens.

In activity terminology it means that expression of association between proliferation and regression within the colony activity field is conditioned by catabolism, differentiation, initiation, and injury.

10. *Halves-Empties* association is decreased by colony influence. The buds, completes, and seniles are reducing factors: the three-quarters fortifying: the brokens non-contributors.

This shows that the buds, the completes, and the seniles are the structures responsible for communal association difference from intrinsic. It means that expression of halves-empties association within the colony set-up is dominantly conditioned by the buds, completes, and seniles.

In activity terminology it means that expression of association between proliferation and catabolism within the colony activity field is dominantly conditioned by proliferation, maintenance, and regression.

11. *Halves-Brokens* association tends to be increased by colony influence. The three-quarters and completes are fortifying factors: the empties and seniles reducing: the buds non-contributors.

This shows that the three-quarters and the completes are the structures responsible for communal association difference from intrinsic. It means that the expression of halves-brokens association within the hydranth family of structures is dominantly factored by the three-quarters and completes.

In activity terminology it means that expression of association between proliferation and injury within the colony activity field is dominantly conditioned by differentiation and maintenance.

12. *Three-Quarters-Completes* association is decreased by colony influence. The brokens, buds, and halves are reducing factors: the empties fortifying: the seniles non-contributors.

This shows that the brokens, the buds, and the halves are the structures responsible for communal association difference from intrinsic. It means that expression of three-quarters-completes association within colony populations is dominantly factored by the brokens, buds, and halves.

In activity terminology it means that expression of association between differentiation and maintenance within the colony activity field is dominantly conditioned by injury, proliferation, and initiation.

13. *Three-Quarters-Senile* communal association is the same as intrinsic. The completes are reducing factors: the buds, halves, empties, and brokens, non-contributors.

This shows that expression of three-quarters-seniles association within the colony setup is essentially uninfluenced by other structures. In other words, the association is independent therefrom and essentially unreactive to colony influence.

In activity terminology it means that expression of association between differentiation and regression within the colony activity field is essentially unfactored and unconditioned by any other activity.

14. *Three-Quarters-Empties* association is increased by colony influence. The seniles and completes are fortifying factors: the buds reducing: the halves and brokens non-contributors.

This shows that the seniles and completes are the structures responsible for communal association difference from intrinsic. It means that expression of three-quarters-seniles association in colony populations is dominantly mediated by the seniles and the completes.

In activity terminology it means that expression of association between differentiation and regression within the colony activity field is dominantly conditioned by catabolism and maintenance.

15. *Three-Quarters-Brokens* association is increased by colony influence. The empties, halves, and buds are fortifying factors: the completes reducing: the seniles non-contributors.

This shows that the empties, halves, and buds are the structures responsible for communal association difference from intrinsic. It means that expression of three-quarters-brokens association in colony population is dominantly mediated by the empties, the halves, and the buds.

In activity terminology it means that expression of association between differentiation and injury within the colony activity field is dominantly conditioned by catabolism, differentiation, and initiation.

16. *Completes-Seniles* association is increased by colony influence. The empties, brokens, buds, and halves are all fortifying factors: the three-quarters are non-contributors.

This shows that the empties, the brokens, the buds, and the halves are structures responsible for communal association difference. It means that expression of completes-seniles association within the hydranth family of structures is factored by all other structures save the three-quarters.

In activity terminology it means that expression of association between maintenance and regression within the colony activity field is conditioned by all other activities save differentiation. That is to say by catabolism, injury, initiation, and proliferation.

17. *Completes-Empties* association is increased by colony influence. The brokens, seniles, and halves are fortifying: the buds and three-quarters non-contributors.

This shows that the brokens, seniles, and halves are the structures responsible for communal association difference from intrinsic. It means that expression of completes-empties association within the colony set-up is mediated by the brokens, the seniles, and the halves.

In activity terminology it means that expression of association between maintenance and catabolism within the colony activity field is conditioned by injury, regression, and differentiation.

18. *Completes-Brokens* association is increased by colony influence. The empties and seniles are fortifying factors: the three-quarters, buds, and halves reducing. The ratio of strengthening frequency to reducing by the empties and seniles is 18:2. The ratio of reducing frequency to strengthening by the three-quarters, buds, and halves is 24:13.

This shows that the empties and seniles are the structures responsible for communal association difference. It means that the expression of completes-brokens association in colony populations is dominantly mediated by the empties and the seniles.

In activity terminology it means that expression of association between maintenance and injury within the colony activity field is dominantly conditioned by catabolism and regression.

19. *Seniles-Empties* association is increased by colony influence. The brokens, completes, three-quarters, and buds are fortifying factors: the halves reducing.

It shows that the brokens, the completes, the three-quarters, and the buds are all structures responsible for communal association difference from intrinsic. It means that expression of seniles-empties association within the Obelia family of hydranth structures is very dominantly conditioned by all other structures save the halves. i.e. By the brokens, the completes, the three-quarters, and the buds.

In activity terminology it means that expression of association between regression and catabolism within the colony activity field is conditioned by injury, maintenance, differentiation, and initiation.

20. *Seniles-Brokens* association is increased by colony influence. The empties and completes are fortifying factors: the buds, halves, and three-quarters non-contributors.

This shows that the empties and completes are the structures responsible for communal association difference from intrinsic. It means that expression of seniles-brokens association within the colony set-up is factored by the empties and the completes.

In activity terminology it means that expression of association between regression and injury within the colony activity field is conditioned by catabolism and maintenance.

21. *Empties-Brokens* association is increased by colony influence. The seniles, completes, and buds are fortifying factors: the halves reducing: the three-quarters non-contributors.

This shows that the seniles, completes, and buds are the structures responsible for communal association difference from intrinsic. It means that expression of empties-brokens association within the colony family of hydranth structures is dominantly mediated by the seniles, the completes, and the buds.

In activity terminology it means that expression of association

between catabolism and injury within the colony field of activity is dominantly conditioned by regression, maintenance, and initiation.

Cringing caution whispers this exposition should have been more safeguarded by the stigmata of indecisiveness: the if: the as if: the could be: the might be: the perhaps: and all the verbal refuges of the irresolute. But dangling thought is a cob-web across the face in the dark. One may get somewhere on the path of clean-cut statement. One may get lost on a path over-grown with hedging. Let the timid interpolate evasions of decision wherever safety dictates. And hesitate. But let the bold state things as they seem. And follow the signs: faint, erratic, and misleading though they sometimes are. New horizons are never seen by those entangled in the thickets. Nor even mirages.

The over-all data (tables 6, 7, and 8) gave quantitative evidence that each definitive hydranth structural state is more or less related to each of the others. The data of table 14 give quantitative evidence that the expression of relation between any 2 structures in colony population is factored by one or more of the other structures.

The 2 sets of data thus establish the fact of general interdependency between the several structural states. And since each is the product of the coming into dominance of a specific growth or plasergic activity (Hammett, 1933: 1936: 1942a: 1942b: 1943a) they also establish the fact that these basic activities are not only inter-related but interdependent.

The whole gives quantitative backing and statement to the postulate derived from observation and reason that an Obelia colony is a concinnate aggregate of interdependent hydranth structures and activities (Hammett and Hammett, 1945).

What these data really do then is give mathematical exposition, confirmation, and extension of the generally accepted postulate that the structures, and the activities which subtend the structures in the life-cycle of growth, maintenance, and dissolution of all organisms, are inter-related and interdependent.

In other words ". . . everything in our experience is only a part of something else that in turn is only a part of still something else . . ." (Fort, 1941).

A working and thinking awareness and acceptance of this principle by all, would lead to less experimentation that is fragmentary, fewer

half-baked interpretations, and more solid and reliable progress in understanding, not only of the world around us, but also of the field of our own diversion.

But it is hardly enough to know there is interdependence. We also want to know the paths and nature of its expression. Analysis of the overall data brought out that colony composition is the product-expression of balanced association between the denominators of growth, maintenance, and dissolution. This shows that the associations constitute a pattern within the colony set-up. It is the pattern of association influence on colony make-up. Is there a pattern of colony influence on association? Answer to this is gotten by appropriate sifting and segregation of the data of table 14.

The table shows that reaction of intrinsic association may or may not be in line with communal association difference from intrinsic. e.g. The buds-halves association is increased by the seniles which is in line with Zero Order difference from 5th: decreased by the empties which is not. Thus two aspects of structure influence on association are had. One is the modification *per se* of intrinsic association. The other the modification which mediates communal association. Basic interest is in the pattern of colony factoring of communal association. But completeness of record requires that pattern of association reaction *per se* be given.

Two measures of structure influence are had. One, the frequency with which association is increased, decreased, and unchanged by a structure. i.e. The brokens provoke 5 of the 11 buds-halves associations to increase: 2 to decrease: 4 to no change. The other measure is the trend of reaction. Since buds-halves associations are increased more than decreased by the brokens, the trend of reaction is to increased association. For this a plus sign is the mark. When associations are decreased more often than increased as is the case in the buds-halves reaction to the empties, the trend is to decreased association. And a minus sign is the mark thereof. When neither increase nor decrease is dominant, as in the case of buds-halves reaction to the completes, no trend is evidenced. This is marked by an equal sign. And so on similarly.

Preliminary work showed that both measures give essentially the same over-all pattern of reaction. Since the trend data are easier to grasp, these will be used for exposition.

I. *Intrinsic reaction per se.* This has 2 aspects. (a) The influence of each structure on the associations. (b) The reaction of the associations of each hydranth state to the structures. The 1st is gotten by counting the number of times a given structure provokes a trend to increase, decrease, and no change in the 15 couplings in which it is an exogenous factor. The table shows the buds provoke a trend to increase in 5: to decrease in 6: to no change in 4. The frequencies so obtained are recorded as percentages under *a* in table 15. And so

TABLE 15

PERCENTAGE FREQUENCY WITH WHICH EACH HYDRANTH STRUCTURE PROVOKES CHANGE IN INTRINSIC ASSOCIATION (*a*): AND PERCENTAGE FREQUENCY WITH WHICH THE INTRINSIC ASSOCIATIONS OF EACH HYDRANTH STATE ARE PROVOKED TO CHANGE (*b*)

	a						*b*					
	Per Cent						Per Cent					
	That Changed				Of Changed		That Changed				Of Changed	
	Tot	+	—	=	+	—	Tot	+	—	=	+	—
Buds	73	33	40	27	45	55	76	43	33	23	57	43
Halves	67	20	47	33	30	70	70	37	33	30	52	48
3-Qts	60	40	20	40	67	33	64	37	27	37	58	42
Compls	80	47	33	20	58	42	80	40	40	20	50	50
Senils	*66*	*53*	*13*	*33*	*80*	*20*	*60*	*53*	*7*	*40*	*89*	*11*
Empts	*87*	*60*	*27*	*13*	*69*	*31*	*80*	*50*	*30*	*20*	*63*	*37*
Brokns	*73*	*53*	*20*	*27*	*73*	*27*	*77*	*47*	*30*	*23*	*61*	*39*
Denominators Of					Grouped							
Growth	67	31	36	33	47	53	70	39	31	30	55	45
Maint	80	47	33	20	58	42	80	40	40	20	50	50
Dissol	*75*	*55*	*20*	*24*	*74*	*26*	*72*	*50*	*22*	*28*	*70*	*30*

on similarly. The 2nd is gotten by counting the number of times the 30 trends of a given hydranth state show increase, decrease, and no change. The table shows the trend of buds association is to increase 13 times: decrease 10: no change 7. These frequencies are recorded as percentages under *b*. And so on similarly.

a. Consider the percentage frequency of change evoked by each structure. Total change is in the 1st column: increase, decrease, and no change in the 2nd, 3rd, and 4th columns: relative increase and decrease in the 5th and 6th. The section shows that—

1. Each structure provokes change more frequently than not. This shows that modification of intrinsic association is the rule.

2. Change is provoked most frequently by the empties. This shows that catabolism is a major factor of association change.

3. Most structures evoke increase more frequently than decrease. This means that increased association is the general reaction to colony influence.

4. Decrease is provoked most frequently by the halves. This shows that proliferation is a major factor of association decrease.

Inspection shows the extent of reaction provoked by the seniles, empties, and brokens differs from that evoked by the buds, halves, and three-quarters. Because of this, and because the seniles, empties, and brokens are product-expressions of activities of common function (dissolution) their influence is combined into one statement and set down in the Dissol. line under the Grouped heading. And since the buds, halves, and three-quarters are product-expressions of other activities of common function (growth), their influence is combined into one statement and set down in the Growth line. Between the 2 is recorded the influence of the completes in the Maint. line. So the 1st line gives the reaction of intrinsic association to the grouped denominators of growth: the 2nd to the denominator of maintenance: the 3rd to the grouped denominators of dissolution. The tabulation shows that—

5. Increased association is provoked most frequently by the seniles-empties-brokens group. This shows that dissolution activity is the dominant conditioner of association increase.

6. Association increase is provoked more frequently by the completes than by the grouped buds, halves, and three-quarters. This shows that maintenance activity is a greater conditioner of increased association than is growth.

7. Increased association is evoked least frequently by the buds-halves-three-quarters group. This shows that growth activity is the least conditioner of association increase.

8. Decreased association is provoked more frequently by the grouped buds, halves, and three-quarters; and the completes, than by the grouped seniles, empties, and brokens. This shows that growth activity, and that of maintenance are greater evocators of association decrease than is dissolution. In turnabout it shows that dissolution activity is the least conditioner of association decrease.

The foregoing shows that the relative influence of the several structures is segregatible into that exerted by the buds, halves, and three-quarters as a group: that exerted by the completes: and that exerted

by the grouped seniles, empties, and brokens. This segregation is the pattern of colony composition as set by the position of the structures in the life-cycle progression, and the nature of the activities which subtend their production. It is also the pattern of integration of colony composition as shown in the analysis of tables 6, 7, and 8, q.v. Thus the differential factoring of association by the denominators of growth, the denominator of maintenance, and the denominators of dissolution gives evidence there is a pattern of colony influence on association. And shows what this pattern is.

b. Consider now the percentage frequency with which the associations of each hydranth state are provoked to change. This is shown in section *b* of the table. The arrangement is the same as that of section *a*. It shows that—

1. The associations of each hydranth state are provoked to change more frequently than not. This means that modification is the rule. It checks with the *a* datá as it should.

2. The general trend of reaction is to increased rather than decreased association. This also checks with the *a* data as it should.

3. The associations of the seniles are provoked to increase more than those of any other hydranth state. This shows that regression relations are more subject to increase than those of any other single activity.

Inspection shows the reaction of the seniles, empties, and brokens differs in degree from that of the completes, and the buds, halves, and three-quarters. So the reactions of the denominators of dissolution have been combined into one statement as in the *a* section: the denominators of growth into another: and the 2 set down along with that of the denominator of maintenance under the Grouped heading. The tabulation shows that—

4. The completes associations tend to react somewhat more than those of the grouped buds, halves, and three-quarters, or the grouped seniles, empties, and brokens. This shows that maintenance relations may be more subject to change than those of growth or dissolution. It is consistent with the concept that maintenance is central in organismic activities.

5. Increase is provoked most frequently in the associations of the seniles, empties, brokens groups. This shows that dissolution relations are most subject to increase.

6. Decrease is provoked more frequently in the associations of the grouped buds, halves, and three-quarters: and those of the completes: than in those of the grouped seniles, empties, and brokens. This shows that growth relations, and those of maintenance are more subject to decrease than those of dissolution. In turnabout it shows that dissolution relations are least subject to decrease.

It is apparent that significant aspects of the relative reactivity of the hydranth states are mirror-images of the relative influence of the structures. Thus—change is more frequent than no change in both: change is generally towards increase in both: and the grouped seniles, empties, and brokens are at one and the same time the most subject to this increase, and the major factor in its production.

Furthermore, while the relative reactivity of the hydranth states associations is not as nicely segregatable as the provocative ability of the structures: nonetheless that of the denominators of dissolution is distinct from that of the denominator of maintenance, and the denominators of growth. And there is some hint of separability between the denominator of maintenance and the denominators of growth in total change. This then is at least a shadow of the same pattern of colony influence on intrinsic association *per se* as that which the relative ability of the structures to provoke reaction gives with definitiveness.

So much for low-power over-all picture. High-power detailed data are wanted for the record. Such are had in table 16. It is itemization of those of table 15 as gotten from table 14.

The horizontal lines give the percentage frequency with which each structure evokes change in the associations of a stated hydranth state. e.g. Table 14 shows the seniles increase association in 4, or 80 per cent of the 5 bud-couplings association in which they are an exogenous factor. This is set down under S (for seniles) in the Buds line of the % INCREASED section. These are itemizations of the *a* data of table 15. Comparing with the frequency of increase evoked by the other structures as set down in the Buds line, it is seen that the seniles are the most potent evocator of increase in buds associations. And so on similarly.

The vertical columns give the percentage frequency with which the associations of each hydranth state are provoked to change by a stated structure. e.g. Table 14 shows that 3, or 60 per cent, of the 5 sets

TABLE 16

PERCENTAGE FREQUENCY WITH WHICH EACH HYDRANTH STRUCTURE CHANGES THE INTRINSIC ASSOCIATIONS OF A GIVEN HYDRANTH STATE (*a*: ACROSS). AND PERCENTAGE FREQUENCY WITH WHICH THE INTRINSIC ASSOCIATIONS OF EACH HYDRANTH STATE ARE CHANGED BY A GIVEN HYDRANTH STRUCTURE (*b*: DOWN)

	% *Increased*							% *Decreased*						
	B	H	T	C	S	E	b	B	H	T	C	S	E	b
Buds	—	0	40	40	80	40	60	—	60	20	40	0	60	20
Halves	20	—	60	20	20	40	60	60	—	20	20	40	20	20
3-Qts	20	20	—	40	40	60	40	60	20	—	40	0	20	20
Comps	20	40	20	—	60	60	40	60	60	40	—	0	20	60
Senls	60	20	40	60	—	80	60	0	20	0	20	—	0	0
Empts	40	20	40	60	80	—	60	40	60	20	40	20	—	0
Brkns	40	20	40	60	40	80	—	20	60	20	40	20	20	—
Denominators Of	*a* Grouped													
Growth	20	40	20	27	40	33	33	40	40	40	53	7	40	33
Maint	40	20	40	—	60	60	60	40	20	40	—	20	40	40
Dissol	60	40	47	53	70	70	60	27	27	13	27	0	10	20
Denominators Of	*b* Grouped													
Growth	20	10	50	33	47	47	53	60	40	20	33	13	33	20
Maint	20	40	20	—	60	60	40	60	60	40	—	0	20	60
Dissol	47	20	40	60	60	80	60	20	47	13	33	20	10	0
	% *Unchanged*							% *Of Changed (Increase)*						
	B	H	T	C	S	E	b	B	H	T	C	S	E	b
Buds	—	40	40	20	20	0	20	—	0	67	50	100	40	75
Halves	20	—	20	60	40	40	20	25	—	75	50	33	50	75
3-Qts	20	60	—	20	60	20	40	25	50	—	50	100	75	67
Comps	20	0	40	—	40	20	0	25	40	33	—	100	75	40
Senls	40	60	60	20	—	20	40	100	50	100	75	—	100	100
Empts	20	20	40	0	0	—	40	50	25	67	60	80	—	100
Brkns	40	20	40	0	40	0	—	67	25	67	60	67	80	—
Denominators Of	*a* Grouped													
Growth	40	20	40	20	53	27	33	33	50	37	33	83	47	53
Maint	20	60	20	—	20	0	0	50	50	50	—	75	60	60
Dissol	13	33	40	20	30	20	20	72	53	81	72	100	90	74
Denominators Of	*b* Grouped													
Growth	20	50	30	33	40	20	27	25	25	71	44	78	55	72
Maint	20	0	40	—	40	20	0	25	40	33	—	100	75	40
Dissol	33	33	47	7	20	10	40	72	33	78	62	74	90	100

of seniles associations in which the buds are an exogenous factor are provoked to increase thereby. This is set down opposite Senls. under B in the % INCREASED section. These are itemization of the *b* data of table 15. Comparing with the frequency with which the associations of the other hydranth states are provoked to increase by the buds, it is seen that those of the seniles are the most affected. And so on similarly.

The *a* Grouped data of table 16 are itemization of those of table 15. They are the averages of the effects produced by the pertinent structures. e.g. The halves effect increase in 0 per cent of the buds associations (Buds line under H). The three-quarters effect increase in 40 per cent (Buds line under T). The average increase provoked by these denominators of growth is 20 per cent. This is recorded under B in the Growth line. The completes effect increase in 40 per cent of the buds associations. This is recorded under B in the Maint. line. The seniles effect increase in 80 per cent (Buds line under S): the empties in 40 per cent (Buds line under E): the brokens in 60 per cent (Buds line under b). The average increase provoked by the denominators of dissolution is 60 per cent. This is recorded under B in the Dissol. line. And so on similarly.

The *b* Grouped data are itemization of those of table 15. They are averages of the reactions of the pertinent hydranth states associations. e.g. Twenty per cent of the halves associations are provoked to increase by the buds (B column opposite Halves): and 20 per cent of the three-quarters (B column opposite 3-Qts.). The average increase reaction of the denominators of growth is 20 per cent. This is recorded in the Growth line under B. Twenty per cent of the completes associations are provoked to increase by the buds. This is recorded in the Maint. line under B. Sixty per cent of the seniles associations are provoked to increase by the buds (B column opposite S): 40 per cent of the empties (B column opposite E): 40 per cent of the brokens (B column opposite b). The average increase reaction of the denominators of dissolution is 47 per cent. This is recorded in the Dissol. line under B. And so on similarly.

With this table one can find out which structure is a major factor of increase, decrease, no change, and net increase in the associations of each hydranth state separately. And which hydranth state is more susceptible to increase, decrease, no change and net increase by each

structure separately. Thus, as noted above: the seniles are the most potent evocator of buds association increase: and the seniles associations show more increase under bud influence than those of the other hydranth states. And so on similarly. To continue—

The Dissol. line in the *a* Grouped data (% INCREASED section) shows that increase is more provoked by the grouped seniles, empties, and brokens than by the completes or the grouped buds, halves, and three-quarters in 5 of the 7 sets of associations. Viz. Those of the buds, three-quarters, completes, seniles, and empties. It also shows superiority in 11 of the 13 comparisons with single items. This can be checked in the detailed data above. The consistency in direction of difference shows the over-all value in table 15 is not unduly weighted. It establishes beyond peradventure the highly significant fact that the general increase in association is dominantly instigated by the seniles-empties-brokens group. And since these are denominators of dissolution it shows that the products of hydranth disintegration key intrinsic association to increase.

The Maint. line of the *a* Grouped data (% INCREASED section) shows that increase is more provoked by the completes than by the grouped buds, halves, and three-quarters in 5 of the 6 sets of associations: less in 1. This, in combination with the above, establishes the separability of the denominators of growth, the denominator of maintenance, and the denominators of dissolution into a pattern of colony influence on association as real.

A thousand and one details of structure influence on association are contained in this tabulation. To give all would be to jam reception inordinately. And anyhow interest here is in digging out the pattern of colony influence on intrinsic association *per se:* not in detail. And this has been done.

To summarize then: Intrinsic association between structures is generally subject to modification by colony influence. The reaction is rather more to increase than decrease. This falls into a pattern composed of the differential effect of the denominators of growth, the denominator of maintenance, and the denominators of dissolution. Which shows there is pattern of colony influence on intrinsic association *per se,* just as there is pattern of intrinsic association influence on colony composition. Q.E.D. Now for—

II. *Intrinsic Reaction into Communal Association.* The preceding

analysis dealt with pattern of structure influence on intrinsic association only. This deals with the pattern of structure mediation of communal association. It is based in the number of times change in intrinsic association is the same as or opposite to the direction of communal association difference from intrinsic. e.g. Table 14 shows that change evoked by the buds is the same in 8, or 53 per cent, of the 15 couplings: opposite in 3, or 20 per cent: indeterminate in 4, or 27 per cent.

Communal association is said to be mediated when the change is the same: opposed when it is opposite: unaffected when indeterminate. So 53 is set down under M (for mediating) in the Buds line of section *a* of table 17: 20 under 0 (for opposing): and 27 under N (for no effectiveness). And so on similarly. The format is the same as that of table 15. The *a* section shows that—

1. Communal association is mediated more frequently than not by all structures save the three-quarters. This shows that mediation is the rule: not the exception. It checks with the data of table 12 in showing that communal association differs from intrinsic more frequently than not. q.v.

2. Communal association is mediated most frequently by the brokens. This shows the brokens are more responsible for communal

TABLE 17

PERCENTAGE FREQUENCY WITH WHICH EACH HYDRANTH STRUCTURE MEDIATES COMMUNAL ASSOCIATION (*a*): AND PERCENTAGE FREQUENCY WITH WHICH EACH HYDRANTH STATE IS MEDIATED INTO COMMUNAL ASSOCIATION (*b*)

By Trend

	a						*b*					
	Per Cent Mediating				Net		Per Cent Mediated				Net	
	Tot	M	O	N	M	O	Tot	M	O	N	M	O
Buds	73	53	20	27	73	27	77	47	30	23	61	39
Halves	67	40	27	33	60	40	70	53	17	30	76	24
3-Qts	60	27	33	40	44	56	67	50	17	33	75	25
Compls	80	67	13	20	83	17	80	60	20	20	75	25
Senils	*63*	*50*	*13*	*37*	*79*	*21*	*63*	*60*	*3*	*37*	*95*	*5*
Empts	*86*	*53*	*33*	*13*	*72*	*28*	*76*	*53*	*23*	*23*	*70*	*30*
Brokns	*80*	*80*	*0*	*20*	*100*	*0*	*77*	*47*	*30*	*23*	*61*	*39*
Denominators Of						Grouped						
Growth	67	40	27	33	59	41	71	50	21	29	71	29
Maint	80	67	13	20	83	17	80	60	20	20	75	25
Dissol	*76*	*61*	*15*	*27*	*84*	*16*	*72*	*53*	*19*	*28*	*75*	*25*

association difference from intrinsic than any other structure. That they are the greatest single mediator of association expression within the colony set-up. And, in activity terminology, that relations between structures within colony populations are conditioned more by injury than any other activity.

3. Communal association is mediated least frequently by the three-quarters. This shows that communal association difference from intrinsic is factored less by the three-quarters than by any other structure. That expression of association within the hydranth family of structures is least mediated by the three-quarters. And, in activity terminology, that relations between structures in colony populations are less conditioned by differentiation than by any other activity.

4. Communal association is mediated more frequently by the completes than by the buds, halves, and three-quarters. Either singly or grouped. This shows the completes are more responsible for communal association difference from intrinsic than the buds, halves, and three-quarters. That they are greater mediators of association expression within the colony set-up. And, in activity terminology, that relations between structures in colony populations are conditioned more by maintenance activity than by that of growth.

5. Communal association is mediated more frequently by the brokens, seniles, and empties than by the buds, halves, and three-quarters. In the orders given: or grouped. This shows the seniles, empties, and brokens are more responsible for communal association difference from intrinsic than the buds, halves, and three-quarters. That they are greater mediators of association expression within the colony set-up. And, in activity terminology, that relations between structures in colony populations are conditioned more by dissolution activity than by that of growth.

The *b* section shows that—

6. Communal association of all hydranth states is more frequently mediated than not. This shows again that mediation is the rule: not the exception. It checks with the *a* data: and with those of table 15. And confirms the observation that communal association difference from intrinsic is the rule.

7. Communal association of the senile correlations is more frequently mediated than that of any other structure. This shows that the associations of the seniles within the colony family of hydranth

TABLE 18

PERCENTAGE FREQUENCY WITH WHICH EACH HYDRANTH STRUCTURE MEDIATES THE COMMUNAL ASSOCIATION OF A GIVEN HYDRANTH STATE (*a*: ACROSS): AND PERCENTAGE FREQUENCY WITH WHICH EACH HYDRANTH STATE IS MEDIATED INTO COMMUNAL ASSOCIATION BY A GIVEN HYDRANTH STRUCTURE (*b*: DOWN)

By Trend

	% *Mediated*							% *Opposing*						
	B	H	T	C	S	E	b	B	H	T	C	S	E	b
Buds	—	40	0	60	60	40	80	—	20	60	20	20	60	0
Halves	60	—	60	40	40	40	80	20	—	20	0	20	40	0
3-Qts	40	40	—	60	40	40	80	40	0	—	20	0	40	0
Comps	60	80	20	—	40	60	100	20	20	40	—	20	20	0
Senls	60	20	40	80	—	80	60	0	20	0	0	—	0	0
Empts	60	20	20	80	80	—	80	20	60	40	20	0	—	0
Brkns	40	40	20	80	40	60	—	20	40	40	20	20	40	—
Denominators Of	*a* Grouped													
Growth	20	60	40	53	40	33	33	40	20	20	27	7	40	33
Maint	60	40	60	—	80	80	80	20	0	20	—	0	20	20
Dissol	60	53	53	67	70	70	50	27	20	13	13	0	20	30
Denominators Of	*b* Grouped													
Growth	50	40	30	53	47	40	80	30	10	40	13	13	47	0
Maint	60	80	20	—	40	60	100	20	20	40	—	20	20	0
Dissol	53	27	27	80	60	70	70	13	40	27	13	10	20	0
	% *Unmediated*							% *Mediating (Net)*						
	B	H	T	C	S	E	b	B	H	T	C	S	E	b
Buds	—	40	40	20	20	0	20	—	67	0	75	75	40	100
Halves	20	—	20	60	40	20	20	75	—	75	100	67	50	100
3-Qts	20	60	—	20	60	20	20	50	100	—	75	100	50	100
Comps	20	0	40	—	40	20	0	75	80	33	—	67	75	100
Senls	40	60	60	20	—	20	40	100	50	100	100	—	100	100
Empts	20	20	40	0	20	—	20	75	25	33	80	100	—	100
Brkns	40	20	40	0	40	0	—	67	50	33	80	67	60	—
Denominators Of	*a* Grouped													
Growth	40	20	40	20	53	27	33	33	75	75	63	83	44	50
Maint	20	60	20	—	20	0	0	75	100	75	—	100	80	80
Dissol	13	27	33	20	30	10	20	72	72	83	81	100	100	64
Denominators Of	*b* Grouped													
Growth	20	50	30	33	40	13	20	63	84	38	83	81	47	100
Maint	20	0	40	—	40	20	0	75	80	33	—	67	75	100
Dissol	33	33	47	7	30	10	30	81	42	55	87	84	80	100

structures is more subject to conditioning than those of any other structure. It means that regression is more subject to modification within the colony field of influence than any other single activity. This checks with its reactivity *per se* to colony influence. q.v.

The pattern of colony mediation of communal association is best gotten from the detail data of table 18. These are itemization of the over-all data of table 17. They are gotten similarly to those of table 16. They are presented in like format for like use. The essential points are given by the *a* Grouped data of the % MEDIATING section. Viz.

1. The Maint. line shows that mediation is effected more frequently by the completes than by the grouped buds, halves, and three-quarters, or the grouped seniles, empties, and brokens, in 4 of the 6 sets of associations. Superiority is also shown in 9 of the 12 comparisons with single items. Like consistency is found in the NET data.

This shows that communal association difference from intrinsic is factored more by maintenance than by growth or dissolution. It means that maintenance is a major conditioner of association expression within the colony set-up.

Thus maintenance emerges, from another and quite different approach, as again primary in equilibration of inter-structural relations in colony populations. The consistency of this phenomenon, combined with the fact it lines up with the general observation that maintenance is primary in organismic activities, stimulates the idea these data and procedures are on the beam.

2. The Dissol. line shows that mediation is effected more frequently by the grouped seniles, empties, and brokens than by the grouped buds, halves, and three-quarters. In 6 of the 7 sets of associations. Like consistency is found in the NET data.

This shows that communal association difference from intrinsic is factored more by dissolution than by growth. It means that association expression within the colony set-up is conditioned more by dissolution than by growth.

These data establish beyond cavil that colony mediation of communal association is differentially effected by the completes: the grouped seniles, empties, and brokens: and the grouped buds, halves, and three-quarters. This segregation is the same as that into which the structures fall naturally on the basis of their position in the life-

cycle progression, and the difference in nature of their subtending activities. It is the same as that which obtains in integration of colony composition. This is as it should be since colony composition is the product-expression of communal association. The concordance of outcome of the 2 different mathematical approaches, and the agreement of both with the obvious pattern of colony organization is all that is sufficient and necessary to prove that there is pattern to colony mediation of communal association. And that this is comprised in the relative influence of the denominators of growth, the denominator of maintenance, and the denominators of dissolution.

The whole boils down to the fact that association expression within the compass of colony populations is the product-expression of a patterned colony inter-structural integration, the accomplishment of which is effected by maintenance, dissolution, and growth activities in the order given.

It is *a priori* evident that the status of any living organism in a given time slice is expression of balance between maintenance, dissolution, and growth of its components. The fact these statistics give mathematical statement to this principle is gratifying. First, because it shows our material is a proper sample. Second, because it shows the procedures are correct, and the results valid indices to inter-structural relations. And third, because the results provide a beginning approximation to quantitative estimate of the intra- and inter-relations of organismic growth, maintenance, and dissolution.

In presenting material such as this one is drawn between the scylla of "If a man were forced to demonstrate . . . all the truths of which he makes daily use, his task would never end" (de Toqueville) and the charybdis of Colby's statement he has ". . . never known a man who could so well digest his information that he did not occasionally show signs of flatulence". Nonetheless there are other items in the communal association bracket which deserve attention.

Table 14 shows that the associations of 14 couplings are increased by colony mediation. It is pertinent to ask: what is the relative effectiveness of the growth, maintenance, and dissolution-expressing structures in the production of this major reaction to colony influence?

The table shows that either the seniles, empties, or brokens condition increased association in 71 per cent of their opportunities therefor: the completes in 45 per cent: the buds, halves, or three-

quarters in 35 per cent. Increased association is thus provoked in colony populations more frequently by the denominators of dissolution, than by those of maintenance or growth. This means that hydranth *zu grunde gehen* is a considerable and major stimulus to tightening-up of inter-structural association within the compass of colony set-up.

This reaction to hydranth loss is what must occur if colony integrity, existence, and continuance as colony is to be maintained. Without such adjustment the colony could not flourish as a green bay tree. As it does: unless destroyed from without. Instead it would be a transitory and evanescent thing. Which it is not. Save under favorable conditions (Hammett, 1943a: Hammett and Hammett, 1945). The concordance of these statistics with the facts of colony living is notable.

Table 12 shows that: (1) Communal association of the completes with the buds, halves or three-quarters is *less* than intrinsic. While (2) Communal association of the completes with the seniles, empties, and brokens is *greater* than intrinsic.

Tables 6 and 7 show that: (1a) The completes are negatively correlated with the buds, halves, and three-quarters. And (2) The completes are negatively correlated with the seniles, empties, and brokens.

(1) plus (1a) shows that contrariety of maintenance and growth expression is *decreased* by colony influence. And (2) plus (2a) shows that contrariety of maintenance and dissolution expression is *increased* by colony influence. This is as it should be.

It is obvious that colony influence on the association of the completes with the buds, halves, and three-quarters is chiefly conditioned by the seniles, empties, and brokens. It has been shown that these are considerable evocators of association increase within the colony set-up. So it is but natural that colony influence should act to *decrease* the negative correlation between the completes and the buds, halves, and three-quarters.

It is also plain that colony influence on association of the completes with the seniles, empties, and brokens is principally conditioned by the buds, halves, and three-quarters. And it can be shown that these are major evocators of association decrease within the colony set-up. So it is but natural that colony influence should act to *increase* the negative correlation between the completes and the seniles, empties, and brokens.

In activity terminology this means that: (1) The expression of antagonism between growth and maintenance tends to be diminished by expression of dissolution activity. And (2) Growth activity tends to increase the expression of antagonism between maintenance and dissolution.

It is by such checking and counter-checking among the big 3 that growth, not only of Obelia colonies but of all organisms, keeps and is kept in equilibrium with living. What these data do is give mathematical exposition of and statement to this basic principle.

Table 14 shows expression of buds-halves association within the colony set-up is conditioned by the seniles. Is this influence more through the buds or more through the halves? It may be assumed that if the seniles are inherently more closely associated with the buds than with the halves, then the conditioning of the buds-halves association by the seniles is exerted more through the buds than the halves. And vice versa.

Table 19 gives the relative frequency of association expressed by the 21 couplings. The position of any coupling in the series tells

TABLE 19

SUMMARIZING RELATIVE EXPRESSION OF CORRELATION

Zero Order

Bb>Cb>Eb>CS>Tb>SE>CE>BT>Sb>BH>BE>HS>Hb>TC>HC>TS>BC>HT>HE>TE>BS

5th Order

Bb>CS>Cb>Tb>CE>BE>Eb>TC>HC>Sb>SE>BC>BT>BH>Hb>HE>HT>BS>TS>TE>HS

Zero Order	*5th Order*
Bb > BT > BH > BE > BC > BS	Bb > BE > BC > BT > BH > BS
HB > HS > Hb > HC > HT > HE	HC > HB > Hb > HE > HT > HS
Tb > TB > TC > TS > TH > TE	Tb > TC > TB > TH > TS > TE
Cb > CS > CE > CT > CB > CH	CS > Cb > CE > CT > CH > CB
SC > SE > Sb > SH > ST > SB	SC > Sb > SE > SB > ST > SH
Eb > ES > EC > EB > EH > ET	EC > EB > Eb > ES > EH > ET
bB > bC > bE > bT > bS > bH	bB > bC > bT > bE > bS > bH

whether the association is greater or less than that of any other. e.g. The intrinsic association of the seniles with the buds (BS) precedes that of the seniles with the halves (HS). This shows the seniles are inherently more closely associated with the buds than with the halves. This being so it is assumed that conditioning of buds-halves association by the seniles is exerted more through the buds than the halves. And so on similarly.

Using this procedure I have sifted out the extent to which conditioning of communal association is effected through each structure. The results are tabulated below as percentages.

B	H	T	C	S	E	b
57	19	14	94	41	47	71

The 57 under B shows that in 57 per cent of the cases colony conditioning of the buds associations with other structures is exerted more through the buds than through any of the conjoined structures. And so on similarly. These data show that:

1. Colony influence is exerted more through the completes than any other structure. This means that maintenance is the chief path through which colony mediation of communal association is effected. Again maintenance emerges as primary.

2. Colony influence is exerted more through the brokens than through any other structure save the completes. This means that colony mediation of communal association is tied up with injury more than with anything else save maintenance. This checks with the obverse obtained in the previous analysis. q.v.

3. Of the denominators of growth, colony influence is exerted more through the buds than through the halves or three-quarters. This means that colony mediation of communal association is effected more through initiation than through proliferation or differentiation. In other words initiation is the chief path of colony mediation of communal association via growth activity.

4. Colony influence is least exerted through the halves and three-quarters. This means that proliferation and differentiation are least utilized as intermediaries in colony mediation of communal association. Again there is check with earlier findings. q.v.

All this adds up to the fact that the completes, brokens, and buds are the chief intermediaries in colony conditioning of interstructural

association. It means that maintenance, injury, and initiation provide the major paths of approach to integration of colony composition.

This is as it should be. For maintenance is basic to colony living, and initiation of new hydranth production to replace hydranths lost by injury is essential to preservation of colony as colony.

The fact the buds are used more than the empties and seniles has like meaning. For it is as important to colony continuance that hydranths lost by regression *cum* catabolism should be renewed as that those lost by injury should be replaced. And this comes first through exercise of the growth activity of initiation. Again cold figures check with the facts of living. And give mathematical statement and exposition of how organismic integrity is maintained not only in Obelia but in all living things through the interdependent expression of growth and plasergic activities.

It is a cliché to state than an organism is a whole, and greater than the sum of its parts. But iteration and reiteration of this basic fact is necessary. Otherwise the trend to compartmentalization in work and thought, with idolization of one aspect and one field will continue increasingly. With information but no knowledge as the ineluctable outcome (Hammett, 1946).

A simple glance at the line of figures given above shows that the frequency with which conditioning to communal association is effected through the denominators of growth as a group differs from the frequency with which it is exerted through the denominators of dissolution as a group. And that the frequency with which conditioning is effected through these differs from that effected through the denominator of maintenance.

This segregation shows that the paths of intermediation fall into a pattern. And that this is the same as the pattern of mediation. This being so no exposition of implications is here needed since such is found in preceding paragraphs. q.v.

Comparison of the chief aspects of human family integration with those of the Obelia family is instructive. In the Obelia family integration is centered in the denominator of maintenance. And human family wholeness centers in the providers. Expression of dissolution activity in the Obelia family evokes closer association between the members. And threat of disintegration in a human family means a closing of the ranks thereof more frequently than not.

But there is more. For just as the buds dominate mediation of colony association by the denominators of growth in Obelia families: so are the babies of all the immature members of a human family the rallying point of attention and care. And just as the brokens dominate the mediation evoked by the denominators of dissolution: so is injury to a member of a human family the occasion of united effort among the others.

If these comparisons and similarities seem fantasies, let the reader ponder the fact that ". . . no completely sane man has a very good time in this world" (Johnson, 1934). That "There is no bar to knowledge greater than contempt prior to examination" (Spencer, 1897). And anyhow ". . . an honest man, and of good judgment, believeth still what is told him, and that which he finds written" (Rabelais).

One cannot help but be intrigued at this similarity of human and Obelia family behavior. And be slyly and wryly amused at human pretense of greatness. But "How can a man be an intellectual leader if he is not quite sure of—his own immense importance?" (Birmingham). "Were it not for dunces we would all be doctors" (Rabelais). It looks as if these data are statistical evidence that "The life of Man, viewed outwardly, is but a small thing in comparison with the forces of Nature" (Russell).

Record, exposition, and meaning of the relative responsibility of the hydranth states for communal association difference from intrinsic is now completed.

To summarize: The extent to which one hydranth state is associated with another when the 2 are by themselves differs from that which they express as members of the colony family of hydranth structures. This shows that intrinsic association is modified by colony influence. And that communal association is mediated thereby.

Analysis brings out that there is pattern to colony mediation of communal association. For this is conditioned most by the denominator of maintenance (completes); next most by the denominators of dissolution (seniles: empties: brokens): and least by the denominators of growth (buds: halves: three-quarters). And this segregation on the basis of differential effectiveness is the same as that into which the structures fall naturally on the basis of their place in the life-cycle progression, and the difference in nature of their subtending activities.

The whole is demonstration that colony inter-structural integration is effected most by maintenance, next most by dissolution, and least by growth. It is mathematical exposition and statement that maintenance is primary in organismic activity. And that living is equilibrated by the interdependent expression of the basic activities of maintenance, dissolution, and growth.

The Obelia data are thus in essential agreement with all correlative observations from all other organisms. As they should be if the concept is well-founded: the material adequate: and the procedure proper.

Relative Expression of Association. Record is wanted of how the association of one coupling compares with that of another. i.e. Of whether buds-halves association is greater or less than buds-three-quarters. And so on. Estimate is based, not on differences in intensity, but on differences in frequency of statistically significant correlation. The reasons are given in the preceding section. q.v. The procedure is the same. Save that there the direction of difference between Zero and 5th Order data was estimated, while here the direction of difference between couplings is gotten.

The results are given in table 19. For the Zero and 5th Order data separately. The long lines show whether the association of a given coupling is greater or less than that of another. e.g. BH precedes HT in the Zero Order seriation. This shows that buds-halves association in colony populations is greater than halves-three-quarters. And so on similarly.

The block data give for each structure separately the relative extent to which it is associated with each of the others. Thus the buds associations with the brokens is seen to be greater than that of the buds with any of its other congeners. And so on similarly.

The table has 2 functions. To serve as reference record for guidance in evaluation of colony reaction to experiment: which will be exposed later. And to provide further information on colony inter-structural integration. Which will be dealt with here.

It would be quite a tour de force to expound all the information given by these data. Comparison of the associative capacity of each coupling with that of each of the others would alone involve statements on 210 Zero and 210 5th Order relations. Answers to the following questions seem primary.

1. Is the association of a structure with those contiguous thereto in the life-cycle progression greater or less than that with the non-contiguous? i.e. Is the association of the seniles with the completes and the empties greater or less than that with the brokens, buds, halves, and three-quarters?

Using the Zero Order block it is seen that: (a) The association of the *buds* with their contiguous *brokens* and *halves* is greater than that with the non-contiguous structures in 7 of the 8 possibilities. (b) The association of the *halves* with their contiguous *buds* and *three-quarters* is greater than with the non-contiguous structures in 6 of the 8 possibilities. (c) The association of the *three-quarters* with their contiguous *halves* and *completes* is greater than with the non-contiguous structures in 3 of the 8 possibilities. (d) The association of the *completes* with their contiguous *three-quarters* and *seniles* is greater than that with the non-contiguous structures in 5 of the 8 possibilities. (e) The association of the *seniles* with their contiguous *completes* and *empties* is greater than that with the non-contiguous structures in 8 of the 8 possibilities. (f) The association of the *empties* with their contiguous *seniles* and *brokens* is greater than that with the non-contiguous structures in 8 of the 8 possibilities. (g) The association of the brokens with their contiguous *buds* and *empties* is greater than that with the non-contiguous structures in 7 of the 8 possibilities.

Succinctly, association is greater with contiguous than with remote structures in 44 of the 56 possibilities: less in but 12. Like analysis of 5th Order data shows association is greater with contiguous structures in 37 of the possibilities: less in but 19.

This is as it should be. For each structure derives from the immediately antecedent in the life-cycle progression and gives rise to the immediately succedent. The relation to contiguous structures is physiologically direct and evocative; while that to structures removed by one or two stages is indirect and conditioning. Again the statistics agree with observation. They give nice exposition that a reaction component of a chain of reactions is more closely related to the reaction from which it derives and to that to which it gives rise, than to the components from which it is removed by intervening reactions.

It will be noticed that superiority of contiguous association is more pronounced in the Zero Order Correlations. This is as it should be. For association is generally increased by colony influence (table 12).

2. Which structure has the greatest associative capacity? Primary aim is to evaluate the significance of inter-structural relations in hydranth populations. These are found in the Zero Order data.

Inspection of this seriation shows that brokens associations occur more often than those of any other structure in the upper third, upper half, and upper two-thirds. So these are in general greater than those of any other structure. Which means that the structures are more tied in with the product-expression of injury than with that of any other single activity. In turnabout it means that injury is the least independent of all activities.

3. Which structure has the least associative capacity? Inspection shows that the halves associations occur more often than those of any other structure in the lower half and lower two-thirds of the Zero Order seriation. So the halves associations are generally less than those of the other structures. Which means that the structures are less tied in with the product-expression of proliferation than with that of any other single activity. In turnabout it means that of all activities proliferation is the most independent.

4. The completes are the central members of the colony family of hydranth structures. Is their association with the buds, halves, and three-quarters on one side different from that with the seniles, empties, and brokens on the other?

The table shows their statistical association with the denominators of dissolution is consistently greater than with the denominators of growth. The differential affords several implications of causality relations depending on where the emphasis is placed. Only one is necessary for exposition. This is that: maintenance is a greater conditioner of dissolution than of growth.

But tables 6 and 7 show the completes are negatively correlated with both groups of structures. So the general statement particularizes into: decrease in the completes conditions a greater increase in seniles, empties, and brokens than in buds, halves, and three-quarters.

Observation shows the completes pass on to seniles, empties, and brokens (Hammett, 1943a). Experience shows this passing on is enhanced by adverse agents such as high temperature, toxic amounts of amino acids, etc. q.v. The result, during a 24-hour interval, is decreased in number of completes. And a concomitant greater increase in number of seniles, empties, and brokens than in number of new

hydranths initiated to replace those lost. Again the statistical associations check with experience.

The difference in increase arises in part because the decrease in completes is effected by harmful stimuli. Which of course act to retard increase in growth expression as they forward that of dissolution. And in part because the new hydranths which derive from empties and brokens cannot appear until the catabolic disintegration of the pre-existing completes is completed. Hence their contribution to increase in number of buds, halves, and three-quarters lags behind the increase in seniles, empties, and brokens.

These then are the reasons why statistical association of the completes with the seniles, empties, and brokens is greater than with the buds, halves, and three-quarters. And why the differential is stated to mean that: change in maintenance expression is a greater conditioner of change in dissolution expression than of change in growth expression. Other meanings are afforded by the differential. But this is the one which fits the facts. And as Pareto writes: it is the facts that make the theories: not the theories the facts.

The major consequence of maintenance activity is substance breakdown: not substance building. It is therefore possible to interpret the differential under comment as statistical statement and exposition that the chemical processes of maintenance are more intimately connected with those of dissolution (catabolism) than with those of growth (anabolism: or constructive substance increase) (Hammett, 1936: 1942a).

5. How does the association between the growth-expressing structures compare with that between the dissolution-expressing?

The SE, Sb, and Eb couplings precede the BH, BT, and HT in 8 of the 9 possibilities (Zero Order seriation). This shows that interstructural association between seniles, empties, and brokens is greater than between buds, halves, and three-quarters. Which means that the product-expressions of dissolution are more closely associated than those of growth.

The differential is probably grounded in the fact that the dissolution-expressing structures are dominately subtended by a single activity,—catabolism: while the growth-expressing are dominately subtended by three,—initiation, proliferation, and differentiation. For it is reasonable to assume that association between successive struc-

tural states produced by one activity should be greater than that between successive structural states produced by three. For the former is not subject to modification by inter-activity checking and balancing as is the latter.

6. Is there pattern to the relative expression of association?

Let the 21 couplings of each seriation be separated into a group of greater and a group of lesser associations. By drawing an imaginary line between the 11th and 12th members.

This done it is found that 83 per cent of the completes associations fall in the upper bracket (5th Order): 67 per cent of the seniles, empties, and brokens: and but 28 per cent of the buds, halves, and three-quarters. Thus inherent associative capacity of the completes is greater than that of the seniles, empties, and brokens as a group: or that of the buds, halves, and three-quarters as a group. While that of the grouped seniles, empties, and brokens is greater than that of the buds, halves, and three-quarters. As shown under 5. This means that associative capacity is greatest in the denominator of maintenance; next greatest in the denominators of dissolution: and least in the denominators of growth.

Thus there is pattern to relative expression of association. And this is the same as that found in other relations. Again maintenance emerges as primary. There is no need to expatiate on these relations. They have been well treated in preceding paragraphs.

Turning now to the Zero Order seriation it is seen that 67 per cent of the seniles, empties, and brokens couplings fall in the upper bracket: 50 per cent of the completes: and 39 per cent of the buds, halves, and three-quarters. Here too pattern is evident. Though not as clean-cut.

The percentage of completes couplings in the upper bracket is less than in the 5th Order seriation. Examination shows the decrease is due to shift of the completes-halves and completes-three-quarters couplings from the higher to the lower bracket. Accompanying this is a shift in the completes-buds coupling to lower place in the lower bracket.

The whole accords with the previous finding that completes associations with the denominators of growth are decreased by colony influence (table 12). The shifts didn't have to happen because a Zero Order association could be less than a 5th without change in position

in the seriation. But that it did happen is nice confirmation of relations previously exposed. q.v.

To summarize: (1) The associations between contiguous structures are greater than those between structures removed from each other by one or more life-cycle stages. This is statistical expression of the truth that each structure is necessarily more intimately related with the one it directly derives from and the one it directly gives rise to in the life-cycle progression, than with the structures with which it has no immediate connection. (2) The greatest associative capacity resides in the brokens. Thus injury is a major conditioner of association. (3) The halves have least associative capacity. Which suggests that proliferation is the most independent of all activities. (4) Association of the completes with the seniles, empties, and brokens is greater than with the buds, halves, and three-quarters. This is partly due to the fact that a major expression of maintenance activity is substance breakdown: not substance building. (5) Association between seniles, empties, and brokens is greater than between buds, halves, and three-quarters. The dissolution-expressing structures exhibit more association because they are product-expressions of but one activity: while the growth-expressing are product-expressions of three. And hence their association is more subject to modification through inter-activity inter-play. (6) There is pattern to relative expression of association. Here as elsewhere the pattern is set by the relative reactivity of the denominators of growth, the denominator of maintenance, and the denominators of dissolution.

Again Obelia family associations have their reflections in human family proclivities. The brokens associations are greater than those of any other structure: and the injured person is a major dependent within the family group. The halves associations are less than those of any other structure: and the young sprouts are noted for their independency. The completes are more negatively correlated with the seniles, empties, and brokens than with the buds, halves, and three-quarters: and the innate antagonism of the providers towards the aged is greater than their annoyance with the children. Finally, just as the association between the denominators of dissolution is greater than that between the denominators of growth: so is clubbiness among the oldsters of a human family greater than among the youngsters. The implication of these and other analogies is that humans are not so much humans as organisms.

Season Difference in Association Expression. For this the data are segregated by month. There are three indices: frequency of significant association: intensity of significant association: and correlation in week-to-week change in percentage contribution to colony composition (Hammett and Hammett, 1945).

Table 20 gives the incidence of significant coefficients in each

TABLE 20
SEASON DIFFERENCE IN EXPRESSION OF ASSOCIATION BETWEEN HYDRANTH STRUCTURAL STATES

A. Difference in *Frequency* of Significant r_{xy} Correlation

	Bud	½	¾	Com	Sen	Emp	Brk	ALL	Bud	½	¾	Com	Sen	Emp	Brk	ALL
	Zero Order *Sr*								Zero Order *PE*							
Apr	8	0	8	25	17	8	17	12	17	0	17	17	25	8	33	17
May	22	8	6	6	14	14	20	13	36	20	20	14	20	22	31	23
Jun	31	10	12	33	20	26	26	22	31	17	20	38	38	40	40	32
July	21	*21*	*24*	*55*	*38*	*33*	45	*34*	38	33	*43*	*64*	*43*	*48*	50	*46*
Aug	*36*	17	*24*	36	20	24	*50*	29	*40*	*36*	31	40	31	43	*60*	40
Sep	29	5	14	14	10	14	29	16	*40*	12	24	24	12	20	50	26
	5th Order *Sr*								5th Order *PE*							
Apr	8	0	8	0	8	0	25	7	33	8	25	25	25	0	33	21
May	17	8	11	8	11	14	14	12	25	14	17	8	22	17	25	18
Jun	21	2	12	24	10	10	17	14	29	17	21	31	17	26	31	24
Jul	17	14	17	*48*	*20*	*20*	*33*	24	21	24	31	*62*	21	*31*	*48*	34
Aug	*40*	*20*	*24*	33	17	17	*33*	*28*	*45*	*29*	29	55	*26*	29	45	*37*
Sep	33	14	12	17	5	12	26	17	36	21	*33*	33	17	17	*48*	29

B. Difference in *Frequency* of Correlation in Change in Per Cent

	Significant					Indicative				
	May	Jun	Jul	Aug	Sep	May	Jun	Jul	Aug	Sep
Net	3	2	6	6	4	3	3	6	5	5
Gross	6	1	6	3	5	4	1	7	3	6

month of record. For each structure separately. And for all combined. As percentages. Thus—there are 6 buds coefficients (BH: BT: BC: BS: BE: Bb) in each of the 7 Augusts of record (1933: 1934: 1935: 1936: 1937: 1938: 1939): or a total of 42. Zero Order table 3 shows that 15, or 36 per cent, of these meet the *Sr* criterion of significance. So this is the percentage frequency with which *Sr*-significant Zero Order buds association is expressed in August. And such is set down under Bud, opposite Aug., in the *Sr* Zero Order bracket. And so on similarly for each structure in each month: for the PE-valid data: and for those of the 5th Order.

The total number of coefficients in all Augusts combined is 21 x 7:

or 147. Table 3 shows that 43, or 29 per cent, of these are *Sr* valid. So this is the percentage frequency with which *Sr*-significant Zero Order correlation is expressed in August. And such is set down under ALL, opposite Aug., in the *Sr* Zero Order bracket. And so on similarly for each month: for the PE-valid data: and for those of the 5th Order.

Table 20 is thus a record of season difference in *frequency* of association expression.

Table 21 gives the average magnitude of the significant coefficients in each month. Plus the Chi square indices to reliability of differences between averages. It is thus a record of season difference in *intensity* of association expression.

The season study showed that the percentage contribution of each structure to colony population varies from week to week (Hammett and Hammett, 1945). It, and table 8 of this study, show inter-structural correlation in this variation. The extent to which this correlation occurs in each month is useful supplement to the present inquiry.

If the percentage shifts are segregated and compared as in table 15 of the season study, q.v., we get the month in which maximum correlation is expressed by each of the 21 couplings. Section B of table 20 gives the number of couplings which express maximum correlation in each of the 5 months of adequate data (May: June: July: August: September). Obviously the month in which maximum correlation is expressed by the greater number of couplings is the month of greatest correlation expression. Distributions are given from Net: Gross: Significant: and Indicative bases. The rationale of which has been exposed in earlier paragraphs. q.v. The Section is thus another and differently grounded record of season difference in *frequency* of correlation expression.

Many workers tend to rely, not on simple arithmetic and common sense for evaluation of differences between 2 sets of data: but on esoteric statistical procedures. What this may lead to is exemplified in table 21.

Numbers are numbers, and one should be able to treat them as numbers. The average value of *Sr*-valid Zero Order May coefficients is 0.358: that of July is 0.370: and that of September 0.433. The May-September differential is greater than the July-September. One might expect the former to be more significant than the latter. But

TABLE 21
SEASON DIFFERENCE IN EXPRESSION OF ASSOCIATION BETWEEN HYDRANTH STRUCTURAL STATES

C. Difference in *Intensity* of Significant r_{xy} Correlation

Zero Order

	Sr-Valid				*PE*-Valid			
A B	Av. r_{xy} A	r_{xy} B	Chi^2	P	Av. r_{xy} A	r_{xy} B	Chi^2	P
May-Jun	.358	.350	.954	.329	.328	.310	*4.919*	*.027*
May-Jul	.358	.370	.280	.597	.328	.329	1.036	.309
May-Aug	.358	.341	1.754	.185	.328	.304	3.418	.065
May-Sep	.358	.433	1.679	.195	.328	.372	2.431	.119
Jun-Jul	.350	.370	.603	.438	.310	.329	2.664	.103
Jun-Aug	.350	.341	.842	.359	.310	.304	2.387	.122
Jun-Sep	.350	.433	*4.377*	*.036*	.310	.372	*7.003*	*.008*
Jul-Aug	.370	.341	1.252	.263	.329	.304	1.246	.264
Jul-Sep	.370	.433	*4.664*	*.031*	.329	.372	*4.966*	*.026*
Aug-Sep	.341	.433	*8.576*	*.003*	.304	.372	*7.640*	*.006*
			5th Order					
May-Jun	.346	.361	.217	.641	.309	.293	*9.887*	*.002*
May-Jul	.346	.337	.306	.580	.309	.302	2.391	.122
May-Aug	.346	.330	.739	.390	.309	.301	1.054	.305
May-Sep	.346	.399	1.543	.214	.309	.347	.772	.380
Jun-Jul	.361	.337	1.420	.233	.293	.302	*4.733*	*.030*
Jun-Aug	.361	.330	2.395	.122	.293	.301	*7.126*	*.008*
Jun-Sep	.361	.399	.696	.404	.293	.347	*14.752*	*.000*
Jul-Aug	.337	.330	.214	.643	.302	.301	.541	.462
Jul-Sep	.337	.399	*4.752*	*.029*	.302	.347	*6.546*	*.011*
Aug-Sep	.330	.399	*6.539*	*.011*	.301	.347	*3.780*	*.052*

the Chi Square analysis "proves" that the larger difference between the May data and those of September is without meaning: while the smaller difference between the July data and those of September is highly significant! Ah! me!

No one would dare claim, and no one would find by Standard Deviation and Probable Error technic, that a difference between averages of 0.008 has meaning when the averages are of the order of magnitude of 0.300. Yet in the 5th Order *PE*-valid series we see that Chi Square analysis "proves" the June average of 0.293 is different from the August of 0.301 to statistically valid degree! And examination of the components of the averages gives no impression of undue weighting. Similar incongruities are scattered throughout the table.

One statistical procedure "proves" no difference: another "proves" there is a difference. Which result is the mathematically unerudite worker to use for decision? I prefer here to use neither. To let the

table stand as a horrible example of what can emerge from hynotic addiction to standard statistical procedure. And to rely on frequency of incidence of significant correlation as given in table 20 for my decisions regarding season difference in association expression. Though the data are frequency data exposition need not be in terms of frequency. It should be clear that if correlation between 2 structures is below par in June (0.020) and above par in July (0.376) association is greater in July than in June (cf. Table 3: Completes-Halves 1938). Ergo the month of greater number of significant coefficients is a month of greater association expression.

The table is evidence enough of season difference in extent of association. Such is shown by the structures individually: by association as a whole: and by the correlation in week-to-week change in per cent contribution to colony populations.

The over-all picture is one in which inter-structural association begins relatively low in April and/or May: rises to a peak in July and/or August: and falls away somewhat in September.

This course of season change in association expression is the same as the course of season change in percentage of completes in colony populations (Hammett and Hammett, 1945). The concordance is intriguing because unexpected. It adds to the already overwhelming evidence that colony inter-structural integration is dominated by the completes. And that maintenance is central in organismic economy. But to explain the differential as solely due to the completes would be to neglect contributory factors of importance.

The general increase of inter-structural association in July and/or August may be interpreted as statistical consequence and expression of increase in stabilization of colony composition. Such as is indicated in the season study (Hammett and Hammett, 1945).

Growth activity is higher in April and May than in July and August. With the result that July and August populations have relatively fewer buds, halves, and three-quarters; and relatively more completes, seniles, empties, and brokens, than those of April and May. In other words July and August populations are more mature than those of April and May. Maturity is a more steady state than immaturity in any organismic assembly. And association is naturally greater in the more steady state since disruptive factors are less and/or lessened. Hence the greater statistical association of July and August here

expressed is a to-be-expected consequence and expression of the shift from colony immaturity to colony maturity through season decrease in growth activity.

Now the season study brought out that there is a late season or September resurgence of growth activity with consequent relative increase in buds, halves, and three-quarters. The bases are there discussed and need no exposition here (Hammett and Hammett, 1945).

If the interpretation just given is well taken it could be expected that expression of statistical association would be less in September than in July and August. The table shows that this is just the case.

So the course of season change in association checks with the course of season change in colony maturity. And in turnabout the course of season change in colony stabilization checks with the course of season change in association expression. As it should. For stabilization of colony composition is indubitably factored by the extent to which inter-structural association is expressed. Everything clicks most satisfyingly.

These things being so it is evident that while maintenance may be primary in season differentials, growth activity also is a considerable factor of importance. And dissolution is not negligible.

Table 20 also shows that by-and-large July is the month of greatest communal association. This is shown both by the coefficients and by the correlations in week-to-week change in per cent. This maximum incidence coincides with the peak of medusae shedding from matured gonangia: with the tapering off of the sharp decrease in bud production: with the tapering off of the sharp increase in percentage of completes: and with a decisive trend to colony composition stabilization (Hammett and Hammett, 1945).

The whole fits in with the argument above. For gonangial maturity and medusal shedding mean lessening of 2 potentialities for disruption of hydranth inter-structural association. The tapering off of sharp shift in buds and completes means maturity attainment: and the trend to stabilization in colony composition means approximation to a more steady state wherein association comes to fuller expression.

To wind up this recital it is not amiss to note that Spring is a time when the members of a human family tend to individually dash off in all directions at once: and that July and August are times of family picnics when all come together in happy association.

EXTRACOMMENT

Two or three other matters are comment worthy.

1. The data afford many more items of significance than are here dwelt upon. Exposition has been deliberately centered on the more general paths of inter-structural association. This does not mean that the subtending inter-communicating net-work of particular relations is unimportant. Far from it. But to clutter presentation with such mass of detail would only obfuscate—not illumine—understanding.

The reader who has a cross-word puzzle mind can find all the needs for enjoyment in the tables. That I have not worked out all the problems for him is perhaps to be regretted. But to have done such would have bored most: lengthened the report beyond reason: and smothered apperception of the data's true significance.

2. Why does colony influence condition a general increase in inter-structural association?

This effect of the whole on association of the parts is not restricted to Obelia colonies. It is also exhibited in the weight inter-relations of the glands of internal secretion in the rat (Hammett, 1926). It is probably a property of all wholeness: organismic and non-organismic.

Organismic wholeness is set by genetically-determined integration of the parts. And this is grounded in the extent of their association. The greater the association the more effective the integration.

Therefore, since progress towards attainment of maximum integration is a basic property of all organisms; wholeness conditions and is conditioned by an increase in association of the parts of the whole. Which isn't much of an explanation after all.

3. The season change in association intensity raises the question as to whether the differential is conditioned by endogenous or exogenous factors.

The differential runs parallel with season shifts in colony maturity. It is explainable on that basis. It has been shown that season shifts in colony maturity are endogenously not exogenously determined (Hammett and Hammett, 1945). So it is reasonable to conclude that the association differential also is endogenously and not exogenously determined.

This is not to assert that temperature, illumination, salinity, plankton and other environmental variables are without influence on asso-

ciation. They are of course of no influence on the nature or kind of association between the chemical reactions of which the life-cycle definitive structures are the product-expressions. These are set by genetic direction and hence impervious in kind and sequence to all but unusual environmental factors. But it is conceivable their *rate* of expression could be differentially affected by virtue of each having an individual temperature, illumination, salinity, and nutritional coefficient. No data at present available allow even a guess of how such may be expressed.

On the other hand, the fact that the variates used in getting these coefficients are of populations collected under all usual variations in environmental factors, justifies the assumption that any exogenous influences are cancelled out. And that the coefficients as gotten are fairly reliable indices of endogenously-determined inter-structural relations. Agreeable to this is the fact that the statistical differentials check with common observation and reason.

The tale is now over. "And if I have done well, and as is fitting the story, it is that which I desired: but if slenderly and meanly, it is that which I could attain unto." Maccabees: II, *15*, 39.

Summary and Conclusions

Analysis is given of the statistical associations between the seven definitive hydranth states of the Obelia life-cycle progression in 3,462 populations composed of 896,302 hydranths on 53,056 colonies. By month and by year. The high findings are:

1. Each structure exhibits more or less association with each of the others. This is statistical consequence of the fact the colony is a concinnate aggregate of inter-dependent structures.

2. (a) The denominator of maintenance (complete hydranths) is negatively correlated with the denominators of growth (buds: halves: three-quarters) on the one side; and the denominators of dissolution (seniles: empties: brokens) on the other. (b) The denominators of growth are negatively correlated with denominators of dissolution (empties: brokens). (c) The denominators of growth are positively correlated with each other. (d) The denominators of dissolution are positively correlated with each other.

The data are definitive mathematical demonstration of what has hitherto been but a postulate from unconnected observations that

integration of organismic living is grounded in the balanced interdependency of the basic activities of growth, maintenance, and dissolution. The which are common to all living things. And that of these activities, maintenance is central.

3. Expression of association between two structures within the hydranth family of structures is conditioned by influences from other members of the family.

This is exerted most by the completes; next most by the grouped seniles, empties, and brokens: least by the grouped buds, halves, and three-quarters. In other words, inter-structural integration in colony populations is effected most by the denominator of maintenance: next most by the denominators of dissolution: and least by the denominators of growth.

This differential is demonstration there is pattern to colony influence on association. For the relative influence of the structures falls into the same grouping as do the structures themselves on the basis of their position in the life-cycle progression, and the difference in the nature of the activities which subtend their production.

The data indicate that maintenance is the primary integrator of organism living: that dissolution evokes a considerable adjustment: and that growth is a least denominator thereof. Which fits the facts of life, since once maturity is attained the chief business of living is energy exchange and replacement of substance lost: not increase in substance or new structures.

4. Greatest inherent association is expressed by the completes: next greatest by the grouped seniles, empties, and brokens: least by the grouped buds, halves, and three-quarters.

This is further evidence that maintenance is a dominant activity in organismic equilibration. It also indicates that expression of growth activity is more independent of that of maintenance than is expression of dissolution activity. The which is substantiated by the fact the associations of the denominator of maintenance with the denominators of growth are less than those with the denominators of dissolution.

5. There is season change in association expression. This starts low in April and May: rises to a peak in July and/or August: and falls away somewhat in September. The differential is attributable, not to season change in environmental factors, but to endogenously determined shifts in colony maturity.

6. The data show that there is close analogy between the basic trends of association between the members of a human family, and the impersonal statistical associations expressed between the hydranth members of an Obelia family. This raises the suspicion that humans are not so much humans as they are organisms.

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THE EFFECT OF SEVERAL LEVELS OF DIETARY CALCIUM AND IODINE ON THE BASAL METABOLISM OF THE ALBINO RAT DURING THE GROWTH PERIOD

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INTRODUCTION

The study of goiter and related conditions of the thyroid gland has been a fruitful field of research for many years. The discovery of the effects on the thyroid of thiouracil and para amino benzoic acid is furnishing yet another method of approach to this problem. The work for this paper was done just before the results of these drugs were demonstrated.

Since the basal metabolic rate is considered clinically as indicative of the condition of the thyroid gland, this was used as the measure of metabolic activity of rats after the various treatments. The conditions especially under consideration were those resulting from various dietary levels of two agents considered goiterogenic, iodine and calcium. Although it was known that thyroidectomy causes a fall and thyroid feeding a rise in the B.M.R., and changes in the parathyroid no change in the B.M.R., it was thought advisable to measure the extent of change resulting from these procedures on the same strain of rats under the same environmental conditions as were used for the feeding experiments. The parathyroid was considered since it plays so important a role in calcium metabolism.

Furthermore opinion seems to be divided as to which gland actually controls the calcium and phosphorus mobilization. Aub, Albright, Bauer and Rossmeisl ('32) gave thyroid medication to hypo-parathyroid patients and found that serum calcium was raised thus alleviating tetany. At the same time the urinary excretion of both calcium and phosphorus was increased. They postulate that this calcium was mobilized from the bones. Cope and Donaldson ('37) report similar results. They believe that thyroid feeding raises serum calcium only within the normal limits for that element but that the administration of parathyroid raises it above normal. On the other hand, clinical

evidence presented by Hansman and Carr Fraser ('38) seems to prove that thyroid *per se* does not have any effect on calcium-phosphorus metabolism. They believe that the apparent effect brought about by the administration of thyroid is the result of some action of this gland on the parathyroid.

Good feeding methods are available today for producing goiter in the rat. Levine, Remington and Von Kolnitz ('33) were able to produce goiter in 35 days by feeding the Steenbock diet supplemented by 0.2% irradiated yeast. The average iodine content of such diets was 15 gammas per kilo, which means approximately 0.15 gamma of iodine per rat per day. Their control diet was the same as the experimental plus KI to make 400 gammas of iodine per kilo of food. The thyroids of their control animals weighed on an average of 12.6 milligrams per 100 grams of body weight while the goitrous thyroids weighed 2 to 10 times as much. Remington and Remington ('38) have shown that normal rats should probably have even smaller thyroids and that with iodine values varying from 265 to 11,380 gammas per kilo of diet the thyroid size ranged from 7.2 to 8.1 milligrams per 100 grams of body weight.

Since the Steenbock diet is badly balanced as to its minerals, having a calcium-phosphorus ratio of 5 to 1, the question might be raised as to the effect of so much calcium as this on the thyroid. These experiments were therefore planned to compare the effects of this Steenbock diet plus several levels of iodine with the same diet modified by substitution of a complete salt mixture for the calcium carbonate and sodium chloride.

Materials and Methods

The three diets used are compared in table 1. The number 351 salt mixture of Hubbell, Mendel and Wakeman ('37) was chosen. Since we wished a very low iodine in the basal diet the KI was omitted from the salt mixture and fed separately as KI solution. Two concentrations were used, one containing 2 gammas of iodine per six drops of solution and the other 2000 gammas per six drops. These were given to the rats with calibrated pipettes, in several hollows on top of the dry food. After a day or two the rats learned to eat these wet balls of food at once. They rarely ever dropped them unless startled. It was easy to check on any loss as the balls were easily seen beneath the cage.

Irradiated yeast was used to furnish both vitamins D and the B complex. From the experiments of Taliaferro ('35) we realized that 0.2% of irradiated yeast as recommended by Levine, Remington and Von Kolnitz ('33) did not furnish enough B complex as the rats developed bare patches in their fur. Therefore 4% of irradiated yeast was used in these diets. Rats on the basal diet (diet A) plus 2 gammas of iodine attained normal size.

The animals used were males from the Wellesley strain of albino rats. They were put on the diets at four weeks of age and weekly basal metabolic tests performed for ten weeks. The normal controls and the operative controls (groups I to VI) were fed on the basal diet A plus 2 gammas of iodine daily. In groups VII to XIV the three experimental diets (Table 1) were used giving three levels of

TABLE 1

MODIFIED STEENBOCK DIETS USED FOR METABOLISM EXPERIMENTS

	Diet A 102.5 gms	Diet B 108.8 gms	Steenbock 104. gms	Steenbock 100.2*
Yellow corn	76 gms	76 gms	76 gms	76 gms
Wheat gluten	20 "	20 "	20 "	20 "
Irradiated yeast	4 "	4 "	4 "	.2 "
Salt mixture 351	2.5 "	2.5 "		
Calcium carbonate			3. "	3. "
Sodium chloride			1. "	1. "
Calcium-phosphorous ratio	1.5/1	8.2/1	4.9/1	4.9/1

*Diet used by Taliaferro.

calcium. With each diet three levels of iodine were fed. Since the 2 gamma level of iodine with normal calcium, diet A, was the control group, this makes eight experimental groups.

Group I. Normal controls. Diet A plus 2 gammas iodine daily.

Operative and Therapy Controls

Group II. Both glands present. Fed 3 doses dessicated thyroid (¼ grain per dose) in the third experimental week and 3 doses (⅛ grain per dose) weekly thereafter.

" III. Both glands present. Injected 3 doses of Lilly parathormone (3 units per dose) in the third experimental week and 3 doses (4 units per dose) weekly thereafter.

" IV. Both glands removed.

" V. Thyroid gland removed; parathyroid transplanted to the salivary gland.

" VI. Parathyroid glands removed.

Experimental Animals

Group VII. Diet *A* with no added iodine.
" VIII. Diet *A* plus 2000 gammas iodine daily.
" IX. Diet *B* with no added iodine.
" X. Diet *B* plus 2 gammas iodine daily.
" XI. Diet *B* plus 2000 gammas iodine daily.
" XII. Steenbock diet, 4% irradiated yeast, no added iodine.
" XIII. Steenbock diet, 4% irradiated yeast, plus 2 gammas iodine daily.
" XIV. Steenbock diet, 4% irradiated yeast, plus 2000 gammas iodine daily.

The rats of the Wellesley strain are especially tame and docile animals and after one morning in the respiration apparatus walk in of their own accord thereafter. Usually they are curled up asleep within 20 to 30 minutes. The experiments were performed over a period of several years, usually between September and May. During these months the rooms containing the animals were thermostatically controlled. For several years the temperature was kept at 22° C. and the basal determinations made at 28° C. Then the question was raised whether the animals could adapt themselves to this higher experimental temperature in the short time allotted to the test. During the last two years therefore the animal room was kept at 27° C. making but a degree difference between the environment and the experimental temperatures.

The basal metabolic determinations were made with a Haldane type open circuit apparatus. The animal chamber was a quart fruit jar to the inside of which a wire mesh platform was attached by strips of adhesive tape. These strips were far enough under the platform so that the rat could not reach them. The jar was fitted with a three holed rubber stopper for inlet and outlet air tubes and a thermometer. The jar was immersed in a water bath kept at 28° C. After a number of experiments it was found that the temperature inside the jar was the same as the water bath when air passed through at the rate of 1 liter per minute. A bright light above the pan induced sleep in the rats. Two such metabolimeters were run simultaneously in the same sink.

Air entered the chamber after passing through calcium chloride and shell caustic tubes. It was also passed through a jar of cotton to clear it of any dust particles since the caustic is very irritating. All tests were made after the animals had fasted for 18 to 24 hours. When the animal had been in the apparatus for at least half an hour and

had been sleeping at least ten minutes, carbon dioxide collections were made by passing the expired air through a set of six U tubes; (1) two calcium chloride tubes to remove the water of respiration, (2) two shell caustic tubes for carbon dioxide absorption, and (3) two more calcium chloride tubes to collect any water set free by the reaction in the shell caustic tubes. The last four tubes were weighed before and after 30 minutes of collection. The difference in weight of the tubes was the rat's metabolism in grams of carbon dioxide. Only quiet periods were used for the experiment, if the animal moved the tubes were disconnected and were connected again after the rat had returned to basal condition. Two or more 30 minute collections were made and the lower value was used as the basal rate for the day. The grams of carbon dioxide per 30 minutes were then converted to calories per 24 hours by the use of the following factors:

1 gram of carbon dioxide equals 0. 5089 liters;

1 liter of carbon dioxide is equivalent to 6.53 calories.

At autopsy the thyro-parathyroid apparatus of each animal was weighed before being preserved. Zenker solution was used with Mallory's triple stain. In the case of the animals whose thyroids had been removed previously, the entire neck region was sectioned. Any fragments of glands still remaining were measured and the volume calculated in cubic millimeters. For the determination of the weight of thyroid material thus expressed in cubic millimeters, several normal glands were both weighed and measured and a factor for converting volume to weight calculated. It was found that 1 cu. mm. of thyroid material weighed 1.53 mgms. All weights of thyroid fragments were calculated from their volumes using this factor. The method of determining volumes from section material has been described in an earlier paper (Hall and Kaan '42).

Results and Discussion

Observations on these various groups included the general appearance of the animals, size and structure of the thyroid gland and the basal metabolic rate.

We kept no day by day activity record but it was quite evident that the animals fed thyroid and those on the high calcium diets were more nervous than the others. There were no evidences of change of position in the eyeballs of any of our rats. Although there

were marked differences in size among the different groups, all were well furred.

Since we were expressing the basal metabolic rate, determined weekly, as a function of body weight, we felt it would be of interest to note comparative size and the growth efficiency of each group. By efficiency is meant the number of grams of food eaten for each gram of weight gained. (Decreased efficiency would mean more food used per gram gained). Comparing all animals with the controls, group I, we find:

1) that in general both growth and efficiency were better on the normal calcium diet than when the calcium level was raised; the exception to this was group XI where high calcium was associated with high iodine (2000 gammas). In this case growth was normal but efficiency was decreased;
2) that parathyroidectomy did not affect body size but efficiency was slightly increased;
3) that injection of parathormone retarded growth but increased efficiency;
4) that both low and high dietary iodine with normal calcium increased growth slightly but decreased efficiency;
5) that the administration of dessicated thyroid with a normal diet retarded growth somewhat and decreased efficiency;
6) that the Steenbock diet with its unbalanced salts retarded growth and decreased efficiency more than did diet *B* with all its salts balanced, except calcium, which was high;
7) that on both high calcium diets the retardation of growth and decreased efficiency were inversely proportional to the amount of iodine present;
8) that thyroidectomy retarded growth considerably and decreased efficiency more than any other procedure used.

A comparison of these rats with those of Halverson, Shaw and Hart ('45) is interesting. They report the extent and type of goiter formation after 13 weeks on an iodine free diet made up with sucrose, soybean globulin, and corn oil plus the proper vitamins and minerals except iodine. The latter was fed in measured amounts daily at three levels 0.5 gamma, 1 gamma, and 2 gammas. Their rats attained the same size as ours on diet *A* plus three levels of iodine, all groups gaining at approximately the same rate. The thyroid size of the animals

TABLE 2

COMPARISON OF THE VARIOUS GROUPS OF ANIMALS AS TO SIZE ATTAINED AND EFFICIENCY OF THE DIET. GROUPS ARRANGED IN ORDER ACCORDING TO BODY WEIGHT.

Group	No. of rats	Diet	Iodine gammas per da.	Av. wt. 13 wks. gms	Weight range gms	Food eaten per gram gained gms	Thyroid mgms. per sq. M. body surf.
VIII. normal calcium	4	A	2000.	193	167-211	6.5	433.
VII. normal calcium	4	A	.14	187	167-208	6.08	991.
I. control	10	A	2.	185	162-202	5.8	423.
VI. parathyectomy	4	A	2.	185	164-209	5.6	529.
XI. high calcium	4	B	2000.	174	162-187	6.9	506.
II. thyroid fed	4	A	2.	171	165-178	6.4	355.
III. parathy injected	4	A	2.	169	160-191	5.3	348.
IX. high calcium	4	B	.14	161	155-169	7.1	1229.
X. high calcium	4	B	2.	161	137-181	6.9	583.
V. thyroidectomy	5	A	2.	148	132-160	8.4	(see table 3)
XIV. medium Ca 4% yeast	2	St.	2000.	143	137-150	7.3	352.
XIII. medium Ca 4% yeast	2	St.	2.	142	126-156	7.4	406.
XII. medium Ca 4% yeast	2	St.	.14	129	122-137	7.9	950.

on their diet plus 2 gammas of iodine was 10.2 mgms. per 100 grams body weight; the thyroids on our diet *A* plus 2 gammas was 6 to 7 mgms. per 100 grams body weight. The goiter produced by the soybean diet and our diet *A* with little or no iodine were about the same. But when our diet B with low iodine was used the goiters were larger.

In a study of the histological appearance of the thyroid gland the animals were considered under the following headings: (1) those on low iodine diets, (2) those on high iodine diets, and (3) those on which operations had been performed.

Lack of iodine caused enlargement of the gland and hyperplasia of the follicular wall. Such glands appear more cellular and seem to have less total colloid than the controls. Measurements of A-9 group VII, and B-1 group IX (table 3) show that although the colloid comprises but 6.7% and 6.9% of the gland substance the much enlarged glands have stored almost the normal amount of colloid, 95.6% for A-9 and more than normal, 116.6% for B-1. This colloid looks different from the normal however. Much of it is colorless globules around tiny points of blue staining material. This combination of columnar cells and colorless globules reminds one of the very active condition present in the thyroid of the developing embryo (Hall and Kaan '42). Dempsey ('44) has shown by iodine analyses and fluorescence studies that strongly fluorescing colloid is rich in iodine. When he caused hyperplasia of the gland by feeding thiouracil the pinpoint areas of colloid in the hyperplastic follicles still showed the strong blue fluorescence. This seems to indicate that the colloid, although small in amount, was still potent. It is not surprising then that the animals on low iodine maintain their basal metabolic rate within normal range. Increase of calcium in the diet in conjunction with low iodine aggravates the hyperplasia. Compare groups VII and IX table 3.

The thyroid glands of animals on high iodine are somewhat smaller than those of the controls (A-11 and A-8, Group VIII table 3.) They appear also to have an increased storage of colloid. The follicles are about the same size as in the controls but seem to lie closer together and contain a denser material. Many follicles stain deep blue or orange. Orange staining colloid, the acid or storage type, appears late in foetal life and in adult life when storage predominates over secretion and is considered to be a more concentrated form than the blue

TABLE 3.

THE AMOUNT OF THYROID TISSUE AND COLLOID PRESENT IN INDIVIDUALS FROM VARIOUS GROUPS, EXPRESSED IN ACTUAL WEIGHTS AND AS PERCENT OF THE AMOUNT PRESENT IN NORMAL INDIVIDUALS.
THE RELATION OF THYROID TISSUE AND COLLOID TO THE BASAL METABOLIC RATE.

Rat	Group	Position of thyroid	Status of para	Body Weight gms	Basal met. rate Cal. per 24 hrs.	Basal met. rate variation from N line	Thyroid actual mgms.	Thyroid per sq. M. surf. mgms.	Thyroid % av. normal	Colloid % total gland	Colloid per sq. M. surf. mgms.	Colloid %-av. normal
Re	I.	trachea	norm.	195	23.4	+ 1.7%	11.87	387.		32.5	126.4	
HH	I.	trachea	norm.	209	24.4	+ 1.6%	12.0	375		32.1	120.3	
Ec	I.	trachea	norm.	200	22.2	— 4.7%	12.88	414.		33.0	136.7	
Average of normals								392.	100.0		127.8	100.0
LLe	IV.	trachea	none	177	20.3	— 5.5%	3.08	107.	27.3	25.3	27.1	21.2
AB	IV.‡	trachea	1 on trach.	201	19.4	—17.0%	.64	20.	5.2	29.8	6.1	4.7
FF	IV.	trachea	none	132	14.2	—19.0%	.67	28.	7.2	32.9	9.3	7.2
EE	V.	sal. gl.	2 in sal. gl.	146	14.6	—23.0%	.94	37.	9.5	15.5	5.8	4.5
DD	IV.	trachea	none	160	14.9	—26.0%	t .54	19.	5.1	17.0	3.4	2.6
		sal. gl.					s .79	29.	7.4	27.9	8.1	6.3
GG	IV.	trachea	none	154	14.2	—28.0%	t .24	9.	2.4	17.4	1.6	1.2
		sal. gl.					s 1.29	49.	12.6	31.6	15.6	12.2
A-9	VII.	trachea	norm.	224	21.9	— 6.4%	61.0	1815.	463.1	6.7	122.6	95.9
B-1	IX.	trachea	norm.	193	19.8	— 7.2%	65.5	2161.	551.2	6.9	149.1	116.6
A-11	VIII.	trachea	norm.	198	20.9	— 6.6%	10.9	353.	90.0	5.3 y 26.7 b	112.9	88.3
A-8	VIII.	trachea	norm.	248	24.8	— .7%	11.9	332.	84.8	10.4 y 18.7 b	90.0	70.4

y—Orange staining dense colloid.
b—Blue staining colloid.
‡—Operated for group IV but one parathyroid found on the trachea.

staining colloid. De Robertis ('41) using the freezing-drying method found that pale blue staining colloid contained more water than the dark blue staining material. This would point to a higher specific gravity of this storage type. Determination of the per cent of colloid gives a normal or slightly low figure (29% to 32%) which applied to the smaller gland gives less total volume stored colloid per animal than in the control. When the thyroids of the two animals, A-8 and A-11, were measured and the weight per cubic millimeter determined the value for the former was 1.78 mgms. and for the latter, 1.97 mgms., in contrast to 1.53 mgms. per cu. mm. for the controls. This furnishes further evidence for the increased density of the orange staining colloid. It would seem, then, that although the gland is smaller and the total colloid less than in the controls the more concentrated material compensates for the lesser volume.

Abnormal follicles were found in animals on 2000 gammas of iodine with both the *A* and *B* diets and also in those on the *B* diet plus 2 gammas of iodine. The colloid stains pale blue and has many floating cells which appear to be degenerating. Examination shows that parts of the follicular wall have torn loose from the supporting membrane and single cells or groups of cells are lying free in the colloid. Whether the thin layer enclosing the colloid mass where the cells have torn free is basement membrane or the enveloping connective tissue is uncertain. Halverson *et al.* ('45) found a condition very similar to this, which they call necrosis, in their rats raised on soybean protein plus iodine in amounts less than 2 gammas.

The thyroidectomized animals with the parathyroid transplanted to the salivary gland (group V) showed varying amounts of thyroid growing at that site. Occasional bits of thyroid were sometimes found on the trachea also. Measurements of the total amounts of such material are included in table 3. The normality of such tissue might be judged by its proportion of colloid to cells, by the appearance of the colloid, and by its efficiency in raising the basal metabolism. Although the thyroid tissue growing in the salivary gland formed colloid more abundantly than did the fragments growing on the trachea the basal rate seems to be correlated with the tracheal colloid rather than with that in the salivary gland. The few animals here represented are not sufficient to establish this point and further work should be done. It would seem from a study of the basal rates and

the amount of colloid present (table 3) that at least 20% of the normal amount must be present for the individual to have a normal basal rate.

Before discussing the data on the basal metabolic rate it is necessary to consider the method chosen for expressing that function. A number of workers have determined the basal metabolic rate for the rat. The criterion for the variation from normal in any particular experimental group has usually been the comparison of such animals with their own controls. Perhaps this is wise since the white rat varies so much in the different laboratories of the country. However, I am not sure that it is necessary. It would be interesting and valuable if we might have a yard stick against which to measure all rats used in metabolic studies. The B.M.R. is expressed variously in the different experiments, often however as calories per square meter per hour. If the animals under consideration are all mature and of the same age this criterion is valid in making comparisons. But since metabolism decreases with increasing age some other method of judging the normalcy of the growing individual from week to week must be sought. A simple available method is that of Benedict as described in Vital Energetics ('38). Here actual calories per 24 hours are plotted against body weight. Benedict has shown that for normal adults regardless of size their calories per 24 hours when plotted against body weight fall along a straight line which lies at an angle between ordinate and abscissa. Many species follow this same rule, the angle of the line depending on the species. The values for any group of normal individuals do not, in general, lie more than 10% above or below this line. Basal determinations on growing individuals are not included in Benedict's work. However this method seemed a good one to use since rats may vary considerably in size at any age. The criterion of normality then for the rats in these experiments has been established by the above method, using ten individuals whose B.M.R. was determined weekly for nine or ten weeks (from 4 weeks to 13 or 14 weeks of age). These rats were fed a standard normal diet, diet *A*, plus 2 gammas of iodine per day. Their determinations were calculated as calories per 24 hours and plotted against body weight (fig. 1). The line corresponding to Benedict's line, about which these figures fall, is called the *N* line. The *N* line is significant for three reasons: (1) the scatter points of all determinations (84

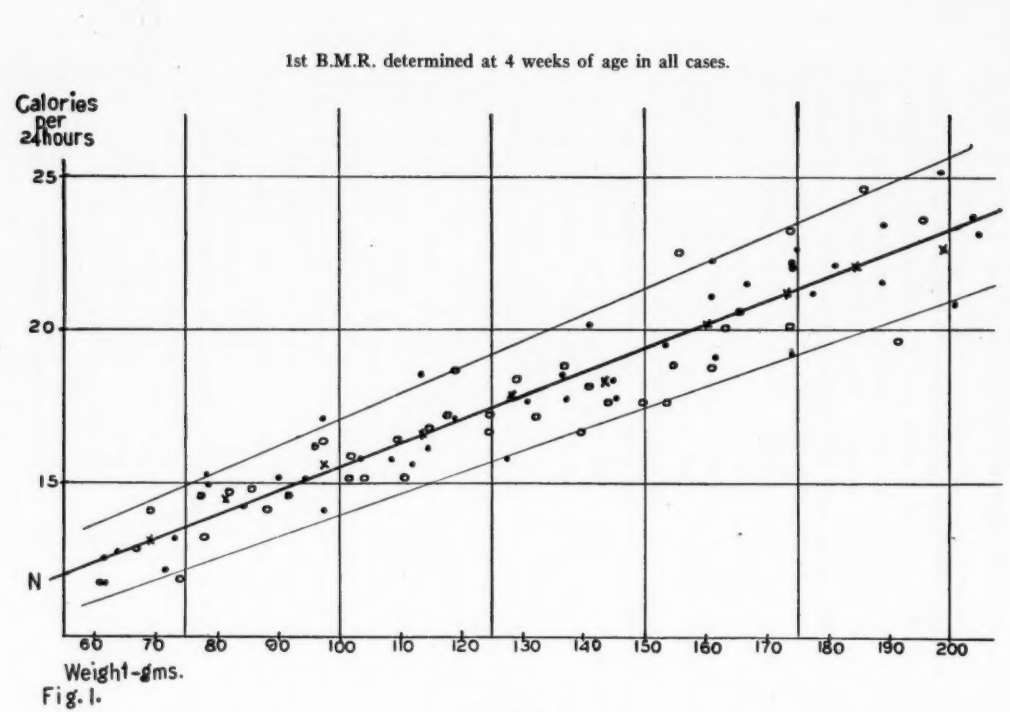

FIGURE 1

Weekly determinations of the basal metabolic rates (calories per 24 hours) of 10 normal growing rats on control diet *A* plus 2 gammas of iodine per day for a period of 10 weeks (group I, table 3). Individuals reared at a temperature of 22° C. marked . ; those reared at 27° C. marked o. Average curve for all individuals, marked x, determines central or *N* line, used in all other graphs as the criterion for normal.

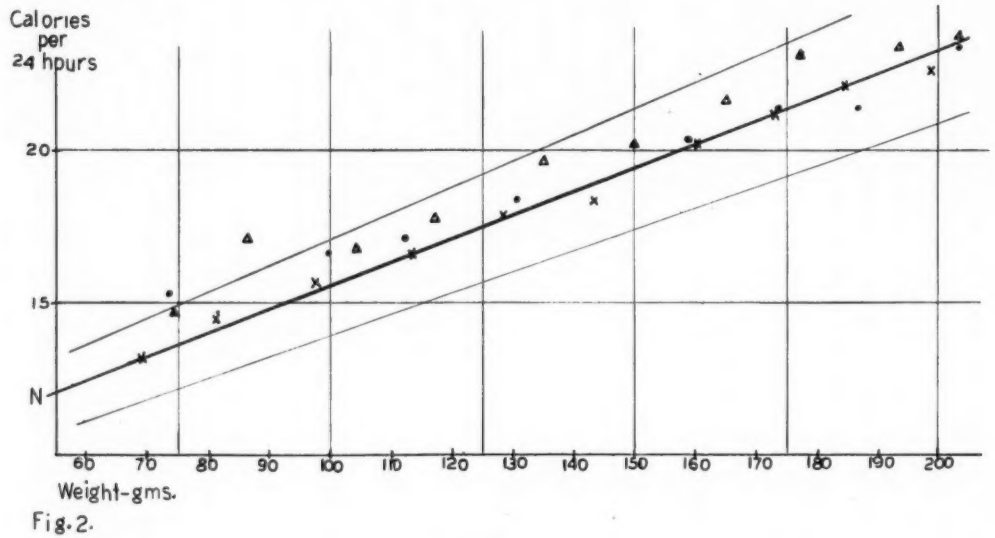

FIGURE 2

Comparison of animals on low and high iodine with the normals. All were fed diet *A* and the B.M.R. determined weekly for 10 weeks. Low iodine, 0.14 gammas daily, average for 4 animals marked . . High iodine, 2000 gammas daily, average for 4 animals marked Δ . Controls, 2 gammas iodine daily, average 10 animals, marked x. Groups I, VII and VIII.

points marked . and o) lie evenly above and below this line, and largely within 10% above and below it; (2) when the weekly average of body weight and calories per 24 hours are plotted as the average curve, the values (marked x) lie very close to this line; (3) the records for several individuals lie very closely along this line throughout the ten weeks. If the record for an individual is above or below the line the ten determinations form a line approximately parallel to the *N* line.

The control animals kept at 22° C. are represented on the graph (fig. 1) by dots and those kept at 27° C. by circles. Apparently this environmental factor made little difference in adjustment to the experimental temperature as both groups are distributed evenly above and below the line.

All other graphs are constructed with this same *N* line as the normal curve of reference. If we compare the B.M.R. of the various groups on the *A* diet we find that neither low (.14 gammas per day) nor high iodine (2000 gammas per day) push the basal values outside the normal range except in the first two weeks of the experiment (fig. 2). The values at this time lie on the upper side of the *N* line almost entirely, showing a slight rise in rate. Feeding thyroid as was expected, raised the rate 20% to 40% above normal, and removing the gland lowered the rate 17% to 30% (fig. 3). All animals with parathyroid gland removed or with parathormone injected lie within the normal range just below the *N* line (fig. 3). The parathyroid hormone does not affect the B.M.R. Chandler and Pickett ('41) report also that the removal of the parathyroid does not change the B.M.R.

The B.M.R. of animals on the *B* diet at all levels of iodine lies within the normal range (fig. 4). Groups on the low iodine and the 2 gammas of iodine are below the *N* line but the 2000 gamma group is quite similar to the control group, lying near or on the *N* line. The rate of groups XII, XIII and XIV on the Steenbock diet with 4% yeast lie within the normal range (fig. 5) except for the third week when the animals on the 2000 gammas of iodine are high. Taliaferro's results ('35) on the same diet, except for low yeast intake (0.2%), have been plotted in fig. 5 for comparison. Her determinations made at 10 and 13 weeks of age only, show that growth was stunted and B.M.R., for a number of the rats, lowered 10% to 25%. This de-

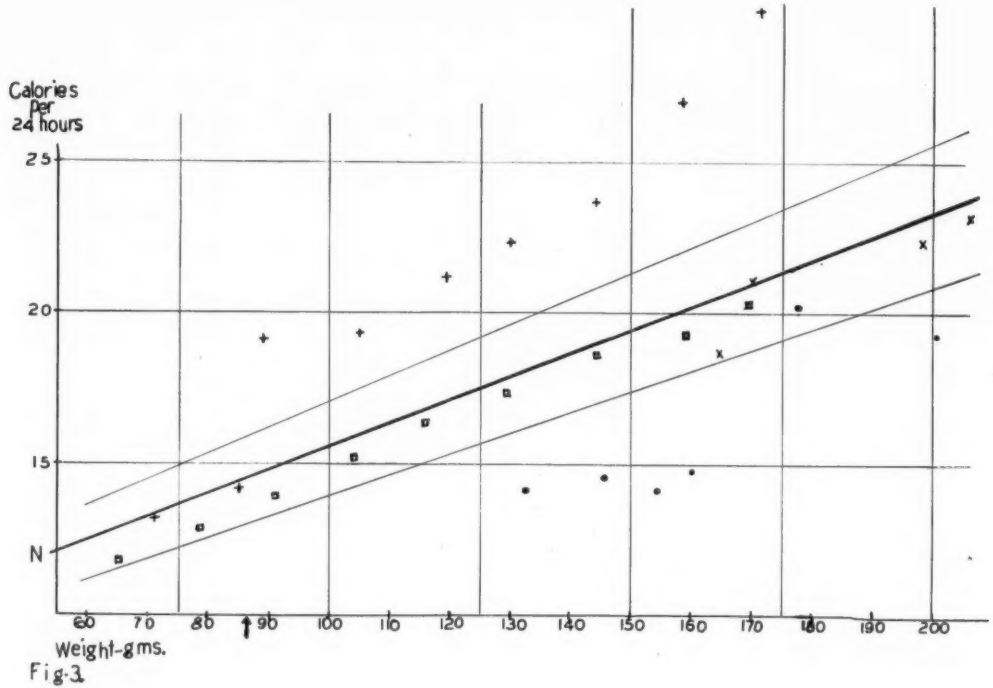

FIGURE 3

Effect of hypo- and hyper-states of the thyroid and parathyroid glands on the B.M.R. All fed diet *A* and 2 gammas iodine daily. Average 4 thyroid fed animals, B.M.R. weekly for 9 weeks, group II, marked +. Average for 4 parathyroid injected animals, B.M.R. weekly for 9 weeks, group III, marked □. Individual determinations of B.M.R. of thyroidectomized animals at 13 weeks, groups IV and V, marked . . Individual determinations of parathyroidectomized animals at 13 weeks, group VI, marked x.

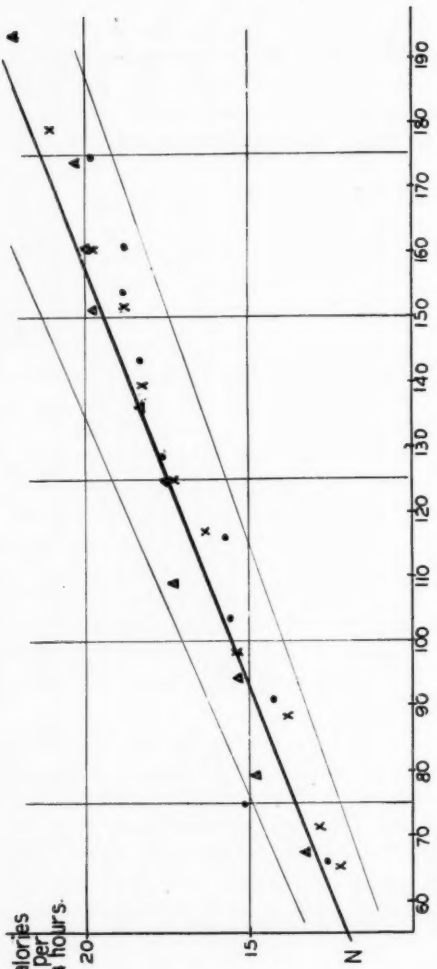

FIGURE 4

Comparison of animals on the high calcium diet, diet *B*, with the *N* line, B.M.R. weekly for 10 weeks. Average for 4 animals, 0.14 gammas iodine daily, marked . . Group IX. Average for 4 animals, 2 gammas iodine daily, marked x. Group X. Average for 4 animals, 2000 gammas iodine daily, marked Δ. Group XI.

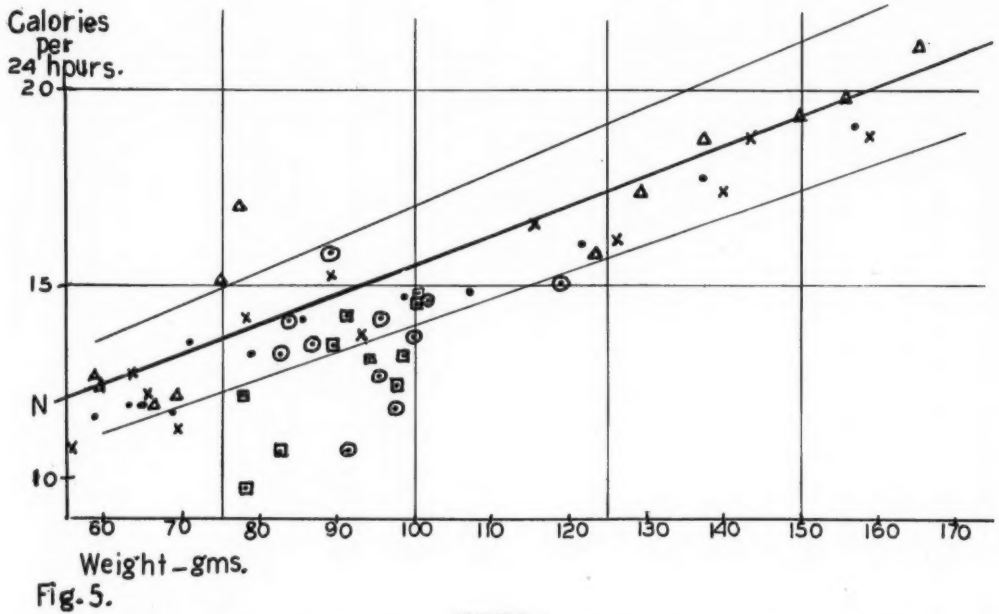

FIGURE 5

Comparison of B.M.R. of animals on the Steenbock diet. 4% of irradiated yeast was used. Three iodine levels: 0.14 gammas daily, marked . , 2 gammas daily, marked x, and 2000 gammas daily, marked Δ. Table 3, group XII, XIII, and XIV. For comparison, Taliaferro's rats on the Steenbock diet with 0.2% yeast have been plotted, age 10 and 14 weeks. Two iodine levels: 0.14 gammas marked ⊙, and about 10 gammas daily, marked ⊡.

pressed metabolism points to a vitamin B deficiency since the B.M.R. of the other Steenbock rats with larger yeast intake were not depressed.

In summarizing the effect of the various procedures on the B.M.R. of the rat we may say that although the lack of iodine may cause hypertrophy of the gland with consequent increase of cell mass and reduction of colloid per follicle, the animal compensates sufficiently by this hyperplasia to furnish the body cells enough thyroxine to sustain the basal level at or near normal. This is true whether the calcium is normal in actual amount and in its ratio to phosphorous, or whether the calcium is high and in abnormal ration to phosphorus. If calcium is high the B.M.R. is low normal but not below minus 10%. When iodine is at a high level the gland stores a denser colloid and, except for the first week or two, does not flood the tissues with extra thyroxine. This high level of iodine together with high calcium gives a B.M.R. like the normal controls.

Conclusions

1) A criterion for expressing the normal B.M.R. for the growing rat has been described.
2) Removal of the thyroid gland depressed the B.M.R. 17% to 30%, and feeding ⅛ grain dessicated thyroid three times weekly raised it 20% to 40%.
3) Neither raising nor lowering the level of the parathyroid hormone had any effect on the B.M.R.
4) Although variations in the calcium and iodine content of the diet induced histological changes in the thyroid gland, physiological compensation was such that the B.M.R. of most individuals stayed within plus or minus 10% of the normal average.

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ABSTRACT

Variations in the thyroid-parathyroid apparatus of rats were obtained in two ways, feeding and operations. Nine groups were prepared by feeding 3 levels of iodine in conjunction with each of 3 levels of calcium. Dessicated thyroid was fed one group and parathormone injections given another. The thyroid glands were removed from one group, the parathyroids from another, and both glands from a third group. These animals were studied as to comparative size, growth efficiency, appearance and size of the thyroid glands, colloid present, and the B.M.R.

A criterion for expressing normal B.M.R. for the growing rat has been described using the determinations made weekly for ten weeks on ten animals. Parathyroid removed or present in excess had no effect on B.M.R. Feeding thyroid raised basal rate 20% to 40% and removing the thyroid lowered it 17% to 30%. Although variations in calcium and iodine content of the diet induced histological changes in the thyroid gland, physiological compensation was such that the B.M.R. of most individuals stayed within plus or minus 10% of the normal average.

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EFFECTS OF THE GROWTH-INHIBITOR, HEXENOLACTONE, ON FLATWORMS.

I. ABSENCE OF AXIAL GRADIENT PATTERN IN THE TISSUE-DIFFERENTIAL RESPONSE

II. CHEMICAL MECHANISM OF TISSUE DAMAGE[1]

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Medawar's (1937) "differential mesoderm inhibitor" has warranted further study for three principal reasons: (1) It produces a reversible check on fibroblast growth in vitro at concentrations not affecting epithelial cells. (2) It occurs in a variety of natural sources, notably malted grains, yeast, orange peels and the ripe berries of the mountain ash, Sorbus. (3) The "synthetic differential growth inhibitor" of Medawar, Robinson and Robinson (1943), probably identical with the malt-distillate factor, has structural similarity with panto-lactone which combines with beta-alanine to form pantothenic acid. This suggested to Medawar et al. (1943) a hypothetical interference of their synthetic delta-hexenolactone with normal pantothenic acid metabolism.

Kuhn and Jerchel (1943) also synthesized an optically active unsaturated delta-hexenolactone and established proof of its structural identity with natural parasorbic acid from Sorbus berries. The biological activity of natural and synthetic parasorbic acid were shown to be identical by Kuhn, Jerchel, Moewus, Möller and Lettre (1943). These authors confirmed the differential inhibition of fibroblasts at concentrations of the lactone which did not affect neoplastic epithelium, and found that addition of excess pantothenic acid did not interfere with inhibition. Similar negative results with pantothenic acid were obtained by us.

[1]Aided by a grant from McNeil Laboratories, Inc.
[2]The expert micro-technical assistance of Miss N. du Bose Maxwell is gratefully acknowledged.

On the other hand, both alpha-alanine and beta-alanine as well as reduced glutathione and cysteine (Hauschka, 1944; Hauschka, Toennies and Swain, 1945) were shown to produce temporary blocking of the inhibitor, while glycine, iso-leucine, glutamic acid and cystine had no such effect. The sulfhydryl antagonism to hexenolactone was demonstrated by bio-assay and its mechanism was studied by colorimetric and spectrophotometric methods (Hauschka et al., 1945).

In our earlier experiments extensive use was made of a number of organisms: *Trypanosoma cruzi,* grown in bacteria-free culture (Hauschka, Maxwell and Johnson, 1945); eggs and larvae of the brine-shrimp, *Artemia salina*; the aquatic annelid, *Dero limosa*; the flatworms *Procotyla fluviatilis* and *Dugesia tigrina* (*Planaria maculata*. All these forms responded to hexenolactone in concentrations ranging from 5×10^{-4}M to 1.25×10^{-5}M. The most specific, reproducible and measurable response was obtained in *Dugesia tigrina* which developed a triclad lesion pattern not in keeping with the axial gradient concept of susceptibility.

The present paper has a threefold purpose: to describe the apparently tissue-differential effect of hexenolactone; to evaluate the dependability of the *Dugesia* lesion pattern in bio-assay; to elucidate the probable biochemical mechanism of hexenolactone activity.

Materials and Methods

Most of the 3548 planarians used in the following experiments were collected by us during the summer months of 1944 in ponds on lower Cape Cod. For work done during the spring of 1945 about 1000 specimens were purchased from the North Carolina Biological Supply House.

These animals were of the same genus and species, formerly known as *Planaria maculata* and *Euplanaria maculata*; but since Hyman's (1939) taxonomic revision, reclassified as *Dugesia tigrina*.

In the laboratory the stock animals were kept in large crystallizing dishes containing filtered pondwater. Once every two weeks they were fed raw egg-yolk, fresh fish-liver, or amphibian blood. The culture dishes were frequently changed and cleaned. Flatworms to be used for experiments were starved for ten days to three weeks, unless otherwise stated. For the 81 separate amino acid tests, 2146 planarians were matched as to size and pigmentation, a control animal

being chosen individually for each test animal. Comparable lots of from 10 to 20 worms were exposed simultaneously to test medium (amino acid plus 5×10^{-5}M hexenolactone at pH 6.7 to 7.0) and control solution (5×10^{-5}M hexenolactone, same pH as test). The covered fingerbowls containing tests and controls were kept in a constant-temperature water bath at 18.6° C. ± 1° C. Measurements of lesion areas were made after 8 to 36 hours of exposure; the majority of measurements were taken between 16 and 20 hours. For measuring, individual animals were removed by means of a wide-mouthed pipette into a Syracuse watch glass. The long and short diameters of the triclad lesions were determined with an ocular micrometer in a 10 X ocular and a 35 mm. objective. Wound areas were calculated in square millimetres/100 (hundredths of square millimetres).

In all the experiments, test and control media were renewed once every 24 hours. Each experiment was checked once daily for 8 or more days to obtain data on acclimatization, healing, and mortality.

Hexenolactone was synthesized by Dr. A. P. Swain of McNeil Laboratories according to the method of Kuhn and Jerchel (1943). The lactone was weighed out in 100 mg. lots into hard glass vials and stored under nitrogen at 4° C. Fresh stock solution of 1×10^{-2}M hexenolactone in distilled water was made up every 3 days, although biological as well as spectrophotometric assays had previously shown considerable stability of the lactone at acid or neutral pH.

The amino acids, glutathione, and other reagents used in our experiments were the purest commercially obtainable. For specially purified cysteine I am indebted to Dr. G. Toennies. The amino acids were stored dry in a dessicator and a 1×10^{-2} stock solution in distilled water was made up immediately before use. Appropriate aliquots of hexenolactone and amino acid stock were then added to filtered pond-water to make up the test and control media.

Sorbic acid, an alcoholic extract of Sorbus berries, and a steam distillate from the latter containing approximately 80% natural hexenolactone, were furnished by McNeil Laboratories.

Tertiary-butyl-hydrogen-peroxide was synthesized by Dr. N. A. Milas of the organic research laboratory at the Massachusetts Institute of Technology.

For histological studies of the hexenolactone effect, specimens of *Dugesia tigrina* were removed from the test media after the triclad

lesion had appeared and during the abortive healing processes. The worms were kept flat between two small pieces of light cardboard and killed with 1% chromic acid before fixation in Kahle's or Bouin's fluid. Serial cross-sections 7 microns thick were stained in Harris' haematoxylin or in Chlorazol Black E, kindly supplied by Dr. H. J. Conn.

Photomicrographs of animals during treatment were taken with a Leitz Micro-Ipso attachment on 35 mm. Kodak Plus-X film through one half of a binocular dissecting microscope. These pictures lack sharp definition since the worms were under water and moving at the time of exposure. The histological sections were photographed through 16, and 4 mm. objectives with the aid of red or green Wratten filters on 3¼ x 4¼ Wratten and Wainwright panchromatic M-plates.

I. The Tri-Clad Lesion Pattern vs. Axially Graded Susceptibility

Since the phylum Platyhelminthes includes the simplest genuinely triploblastic forms, it was thought that a "differential mesoderm inhibitor" would damage the flatworm mesenchyme, yet leave epidermis, nervous system and intestine relatively unaffected.

In an exploratory experiment the heads were cut from 50 specimens of *Dugesia tigrina*. Half the worms were put into 5×10^{-5}M hexenolactone in pond water, the rest served as controls. All the controls regenerated new heads within 8 to 14 days. The test animals not only failed to show regeneration beyond a slight head-cone, but after about 12 hours of exposure developed three lesions each in the dorsal body-surface overlying the tri-clad intestine. In approximately three-fourths of the test animals these wounds became progressively larger; this was followed by death within 8 days. The survivors exhibited abortive attempts at repair. The wounds became covered with a pigmentless sheath of epithelium not supported from below by mesenchyme tissue (fig. 12). The epidermis formed hollow knobs, and the animals eventually succumbed unless removed to pond water before the damage was too extensive.

The unique tri-clad dorsal lesion pattern occurred with such regularity that it was decided to discontinue the use of decapitated planarians and to expose intact worms to hexenolactone media for closer study of the apparently tissue-differential effect. At the same time

the lesion size and pattern could serve as quantitative index of hexenolactone activity in the presence of hypothetical inactivators of the inhibitor (to be discussed in Part II).

Of the over 3000 animals used in the various experiments designed to elucidate the biochemical mechanism by which the lactone affects tissues, one-half were hexenolactone controls and the following observations are based on them.

The hexenolactone concentration in all the experiments was 5×10^{-5}M (or about one half the mesenchyme-inhibiting concentration used by Medawar et al., 1943) since it was found that 5×10^{-4}M produced the triclad split followed by general cytolysis and death within only a few hours, while 1.25×10^{-5}M had no outward effect over indefinite periods save for a slight increase in the frequency of transverse fission (vegetative reproduction).

Figs. 13 and 14 give the typical appearance after about 20 hours of exposure, the earliest signs of damage appearing between 8 and 12 hours. There was no visible injury whatever in the head and extreme tail-tip regions, or on the ventral surface.

The wounds coincided with the pattern of the underlying three-branched intestine (fig. 15). The order in which these lesions first developed was not fixed; sometimes rupture of the epidermis overlying the anterior gut preceded posterior damage, but the opposite was equally frequent. The heads in figs. 13 and 14 seem contracted; this impression is caused merely by foreshortening of the raised anterior end; the tail is evidently curled upward and forward. This characteristic fixed pose assumed by worms after the appearance of the dorsal lesions (fig. 16) was rigidly maintained by most animals until the center of the body had disintegrated, and suggests unequal damage to the antagonistic musculature.

The two posterior lesions usually merged (fig. 18), the proboscis was frequently lost, and the central and posterior portions of the body disintegrated a day or two before the head.

It is a well-known fact that isolated flatworm heads are as a rule incapable of regenerating, and survive for only a few days in pond water.

A check based on 1800 specimens of Dugesia still alive on the 5th day of exposure to hexenolactone showed that 57 had shed their heads which usually were still intact (fig. 17), and 222 were without pos-

terior mid- and hind-body. The rest had only the triclad lesions. The ratio of lost posterior end to severed head (3.89) is in quantitative keeping with the relative antero-posterior distribution of the three-branched intestine.

The classical symptoms of axially-graded susceptibility, beginning with disintegration of auricles and tip of head and progressing down the main axis of the body toward the center, were never produced by hexenolactone. Serial cross-sections through hexenolactone-treated animals with triclad lesion do not reveal any histologically apparent damage in the head region (fig. 19) or extreme tail-tip, while damage in the areas surrounding the intestine (figs. 21, 23, 25) is obvious.

The absence of lesions from the ventral surface, and their consistent appearance in the dorsal body wall, is not necessarily conditioned by a "dorso-ventral gradient", but can be explained on anatomical grounds, the ventral body wall being considerably thicker and more distant from the intestine. Hence the tissues underlying the dorsal epidermis would be reached by toxic substances sooner, regardless of whether diffusion takes place from the gut outward or from outside inward. As there is no visible injury to the epidermal elements, even in the areas immediately surrounding the lesions, it is reasonable to assume that injury to, or inactivation of, the tissues underlying the dorsum is a prerequisite for the triclad lesion. Whether intestinal epithelium is damaged prior to mesenchyme and musculature, is difficult to determine. Loss of the proboscis by many of the treated animals, and sloughing-off of intestinal diverticula through the wound areas indicate considerable response of the gut-tissues to hexenolactone.

Epidermis, on the other hand, not only appears least affected, but is able to form sheaths of apparently new growth over the wound areas (fig. 26). These sheaths are thicker than the epidermis elsewhere, being two cell-layers deep, and contain unusually large numbers of rhabdites. They are not contiguous with mesenchyme beneath, and sometimes assume bizarre sponge-like papillomatous contours. All this suggests that epidermis is still capable of temporary repair growth after the intestine is severely damaged and mesenchyme can no longer proliferate, i.e., tissue-differential response.

Cytological differences between test and control tissues are not as marked as the very obvious histological derangement produced by

hexenolactone. Control sections seem to have thinner epidermis with fewer secretory vacuoles than treated material. The dorso-ventral muscle strands are intact, and the clearly outlined intestine is supported by a spongy mesenchyme framework. In the tests (fig. 27) the cells of the disorganized intestine show perhaps more vacuolization than corresponding control tissues (fig. 28), and the gut is disconnected from mesenchyme. The latter contains a few scattered necrotic cells and some pycnotic or degenerate nuclei. The musculature and ciliation of the proboscis (fig. 23) look intact.

In spite of the scarcity of really clear-cut effects on the cytological level, a comparison between test sections (figs. 21, 23, 25, 26, 27) and control sections (figs. 22, 24, 28) is strongly suggestive of tissue-differential disintegration.

II. Biochemical Mechanism of Hexenolactone Activity

The experiments described below are concerned with: (1) The specificity of the triclad lesion patten; (2) the degree of constancy of lesion area; (3) the effect of intestinal contents on lesion pattern; (4) the possibility of a peroxide effect similar to that produced by angelicalactones (Mendez, 1944); (5) the alanine antagonism to hexenolactone (Hauschka, 1944); (6) the sulfhydryl reactivity of hexenolactone (Hauschka et al., 1945); (7) the effect of serum on hexenolactone activity.

1. The triclad lesion pattern appears to be a specific hexenolactone effect. It was produced only by synthetic delta-hexenolactone and by a steam distillate obtained from an alcoholic extract of Sorbus berries containing approximately 80% natural parasorbic acid. The structurally similar isomere sorbic acid, maleic anhydride and maleic acid (fig. 1) produced no lesions. Sorbic acid at a concentration of 5×10^{-4}M was lethal within 8 hours, but there was no axially graded susceptibility. At 5×10^{-5}M (the concentration used in all the hexenolactone experiments) sorbic acid produced no injury over indefinite periods.

Maleic anhydride 5×10^{-4}M caused death within 66 hours, again without the triclad lesion pattern and without signs of differential susceptibility. Worms kept in a 5×10^{-5}M solution of this compound for two weeks appeared normal. Maleic acid had no effect at 5×10^{-4}M and 5×10^{-5}M.

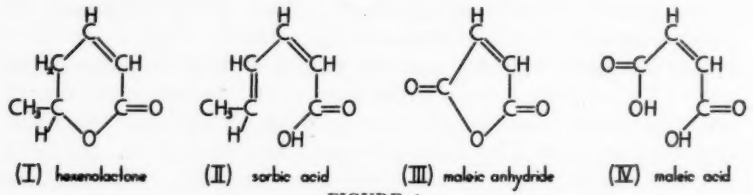

FIGURE 1

MOLECULAR STRUCTURE ESSENTIAL FOR TRICLAD LESION EFFECT

Only hexenolactone (I) produced the triclad lesion pattern in Dugesia tigrina. Compounds II, III, and IV at various concentrations had no such effect.

The triclad lesion pattern could not be produced by exposing animals to distilled water, various concentrations of seawater, 0.5% chloretone, 0.5% MS_{22}, saturated aqueous solution of magnesium chloride, 2×10^{-4}M potassium hydroxide, 2×10^{-5}M potassium cyanide, or 1×10^{-3}M potassium cyanide. In the latter medium death occurred within 45 minutes and clearly followed the axial gradient pattern, with disintegration of the head preceding general cytolysis.

None of the several concentrations of inorganic peroxide or of tertiary-butyl-hydrogen peroxide produced the triclad dorsal lesions. In the presence of 1×10^{-3}M inorganic peroxide and 1×10^{-4}M tertiary-butyl-hydrogen peroxide differential disintegration, beginning with the auricles and tip of head, followed the "Child pattern". Tertiary-butyl alcohol at 1×10^{-4}M, used as solvent for the organic peroxide, produced no lesions.

These tests, carried out on a total of 1402 animals, indicate considerable specificity of the hexenolactone-produced lesion pattern. No reference to a similar pattern was found in the extensive literature dealing with the effects of many toxic substances on flatworms.

2. Although lesion size varies considerably from animal to animal, average lesion area for lots of 20 to 40 hexenolactone-treated worms is remarkably constant. In 7 groups of 20 to 40 animals each, chosen at random and measured after 18 to 19 hours of exposure, average lesion size in $mm^2/100$ was as follows: 39.9, 39.9, 39.7, 36.8, 35.9, 34.4, and 30.4; a range of approximately $\pm 12\%$ from the median value.

One hundred animals were carefully matched and set up in four different paired experiments in 5×10^{-5}M hexenolactone in pond water. One set was designated as "A", the other as "B". After 17

to 20 hours, the 4 lots of "B" differed from the corresponding lots of "A" as follows: —11.9%, —5.8%, —3.4%, +11.4%. These differences are insignificant and again suggest a variation of only about ±12% from "A".

From the above it is evident that the relative constancy of lesion size permits the use of lesion area in matched animals as a quantitative criterion of hexenolactone activity.

3. When recently-fed worms were exposed to hexenolactone, lesions appeared more rapidly and were usually more extensive than in starved worms. Average wound-area in 4 series, comprising 40 well-fed worms each, after 18 hours of exposure was found to measure 31.7, 43.9, 47.5, 59.3 $mm^2/100$. This range of 31.7 to 59.3, as compared with the considerably smaller range in animals starved for 10 days (see above), shows how feeding increases experimental variability, and why it should be avoided for at least a week preceding experiment. The differences in percentage survival between starved and fed lots are also evident from figs. 3 and 10.

4. Mendez (1944) has recently reported that the cardiac activity of the angelicalactones (which bear structural similarity to the gamma-lactone rings in the side-chains of certain aglycones of the digitalis group) may be directly ascribed to peroxides formed in aqueous solutions in the presence of metallic impurities. The peroxide effect on heart muscle was counteracted by cysteine, glutathione, and other SH compounds. Presumably, the sulfhydryl prevented the oxidation by forming complexes with the metallic catalysts.

Analysis of delta-hexenolactone solutions, such as those used in our *Dugesia* experiments as well as much higher concentrations, gave no positive tests for peroxide even after prolonged aeration in the presence or absence of either copper or flatworm tissues. Our findings for delta-hexenolactone are not to be taken as contradicting Mendez' results with gamma-angelicalactone. Attempts to reproduce the triclad lesion pattern in *Dugesia tigrina* with either inorganic peroxide or with tertiary-butyl-hydroperoxide (see above) were unsuccessful; hence it may be concluded that hexenolactone does not exert its biological effects through peroxide formation.

5. In earlier experiments (Hauschka, 1944), designed to test the hypothesis of Medawar et al (1943) that hexenolactone somehow entered into pantothenic acid metabolism, pantothenic acid did not

weaken the activity of hexenolactone. On the other hand, both alpha-alanine and beta-alanine, as well as glutathione and cysteine, were shown by us to inactivate the inhibitor. Glycine, iso-leucine, glutamic acid, and cystine had no such effect.

The experimental results based on lesion measurements in 81 separate tests performed on 2146 matched animals are condensed in Table 1. The test-medium in each case consisted of test-substance

TABLE 1

ACTIVITY OF 5×10^{-5}M HEXENOLACTONE (=10%) OVER A PERIOD OF 20 HOURS, AS INFLUENCED BY THE ADDITION OF VARIOUS AMINO ACIDS AND A TRI-PEPTIDE

Effect	% Activity	Test substance in n x 10^{-5} moles per liter added to 5×10^{-5}M hexenolactone	n
I Significant Inactivation	0	Cysteine	25.0
	35.3	Glutathione	25.0
	49.0	Cysteine	2.5
	62.2	Glutathione	2.0
	67.5	Beta-alanine	5.0
	68.2	Beta-alanine	2.5
	69.9	Glutathione	5.0
II Within range of standard control variability	96.5	Beta-alanine	20.0
	100.0	Hexenolactone	Control
	101.4	Cystine	12.5
	106.6	Iso-leucine	5.0
	111.6	Iso-leucine	2.0
III Activation or double toxicity	122.3	Glycine	1.0
	124.5	Cystine	2.5
	125.1	Glycine	2.5
	132.5	Glutamic acid	2.0 pH adjusted
	160.5	Glutamic acid	2.0 pH not adjusted

plus 5×10^{-5}M hexenolactone at pH 6.7 to 7.0; the control solution was 5×10^{-5}M hexenolactone, same pH as test. Control solutions of the amino-acids alone in corresponding concentrations were not noticeably deleterious to the flatworms.

In Table 1, hexenolactone activity in the presence of test-substance is expressed in per cent of the corresponding hexenolactone control. The manner in which these activity values were obtained, as well as the consistency of the results, should be evident from the following tables and charts. Not all the tabular material could be included in the present report.

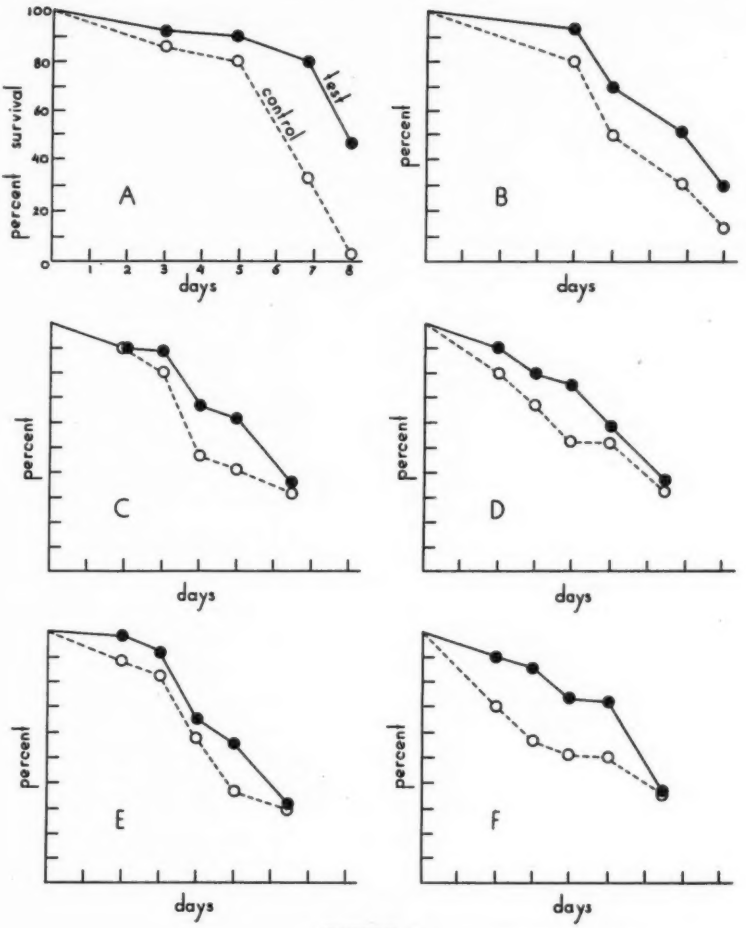

FIGURE 2

EFFECT OF BETA-ALANINE ON SURVIVAL OF DUGESIA TIGRINA IN HEXENOLACTONE MEDIUM
Each of the six graphs is based on 30 animals. The hexenolactone concentration in all cases was 5×10^{-5}M. In graphs A and B, β-alanine concentration was 5×10^{-5}M; in C-F it was 2.5×10^{-5}M. The deviation of test curves from corresponding controls is consistent.

TABLE 2

LESIONS PRODUCED IN DUGESIA TIGRINA BY HEXENOLACTONE AND THE COMBINED EFFECT OF HEXENOLACTONE AND β-ALANINE

H=Hexenolactone
HA=Hexenolactone plus β-Alanine
*=Second measurement on preceding lot

Series, Molarity in n x 10^{-5}M	No. of exp.	Number of worms	Hours	Total lesion area in $mm^2/100$ H	HA	% Diff.
		40	18	357	331	+ 7.7
I		40	19	2131	2027	+ 5.2
H n=5	5	40	22	2269	2456	− 8.3
A n=20		40	23	1937	1984	− 2.5
		40	24	1874	1472	+27.3
		30	24	1253	876	+43.0
		—	36	1501*	1026*	+46.3
II		30	28	1763	1109	+59.0
H n=5	5	40	16	845	712	+18.9
A n=5		40	17	2009	998	+101.3
		40	18	1171	1040	+12.6
		30	16	362	214	+69.0
		—	22	1360*	1074*	+26.6
III		30	16	1011	863	+17.1
H n=5	5	30	17	1084	737	+47.0
A n=2.5		30	9	163	58	+179.6
		30	15	802	473	+69.7
		—	22	2029*	1230*	+64.9

The beta-alanine data are summarized in Table 2. It is interesting that beta-alanine was without effect at 20 x 10^{-5}M, and that both the weaker concentrations consistently counteracted the lactone. The reproducible nature of this effect is also evident from fig. 2, which represents 6 separate plottings of survival and shows a consistent positive deviation of the alanine tests from their respective controls.

Fig. 3, previously referred to, illustrates the effect of starvation and feeding on survival in hexenolactone medium, as well as the absence of an alanine effect on survival at an alanine concentration of 2 x 10^{-4} M.

Table 3 and fig. 4, summarizing the results obtained with d-isoleucine, are not indicative of significant differences between test and control lesions or survival.

Glycine (Table 4), in both the concentrations tested, added to the toxicity of hexenolactone. The probability that the test and control results presented in this table do not differ from one another is less than 0.0098, as calculated by Wilcoxon's (1945) Ranking Method.

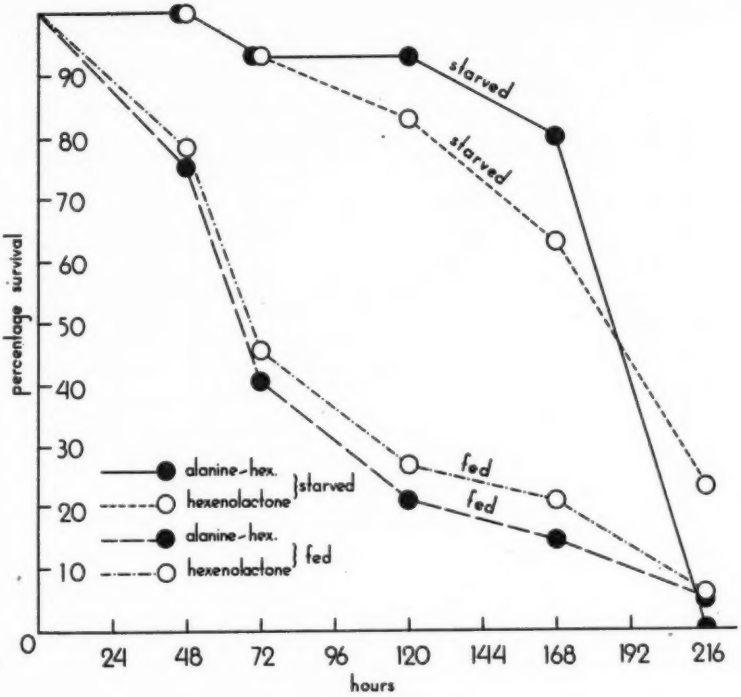

FIGURE 3

EFFECT OF BETA-ALANINE (20×10^{-5}M) AND STARVATION ON SURVIVAL OF DUGESIA TIGRINA IN HEXENOLACTONE (5×10^{-5}M)

In keeping with data on lesion size (Table 2), the higher concentrations of beta-alanine do not counteract hexenolactone damage. Starvation delays death. This graph is based on 200 animals.

The statistical significance of some of the other data presented in Table 1 was likewise analyzed according to Wilcoxon. This procedure for comparing the means of two groups utilizes the magnitude of the differences as well as the signs. It has higher efficiency than Friedman's test of Significance, which is based merely on the number of positive and negative differences.

Figs. 5 and 6 represent the absence of an effect of two concentra-

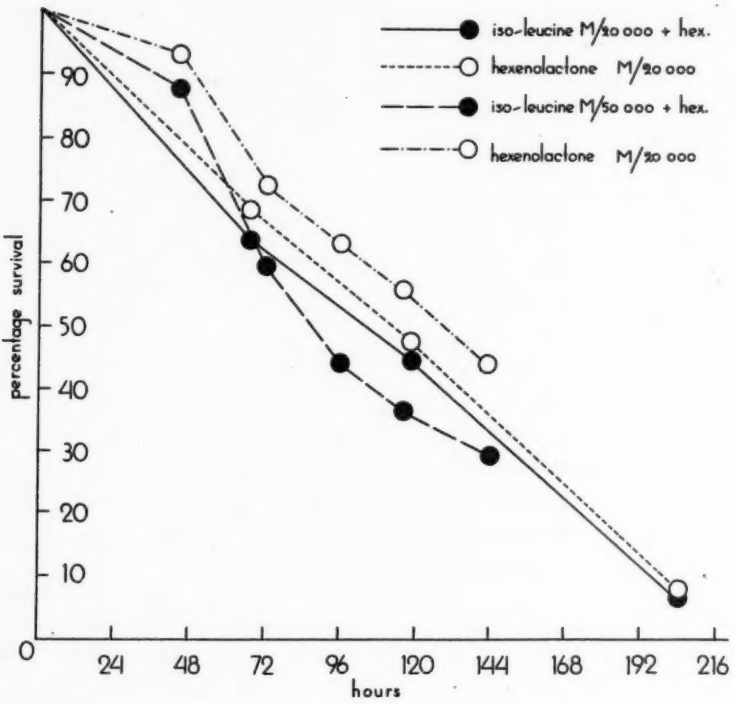

FIGURE 4

ABSENCE OF ISO-LEUCINE EFFECT ON SURVIVAL OF DUGESIA TIGRINA IN HEXENOLACTONE MEDIUM

Each of the four curves in this graph is based on 100 animals.

tions of glycine on survival. These graphs are based on 200 animals each, and show striking coincidence of mortality curves.

Glutamic acid (Table 5), like glycine, adds to the toxicity of hexenolactone, especially when the pH of the test solution is not adjusted. The latter result could possibly be due to the known greater stability of the lactone at higher acidity.

6. The consistency of the cysteine effect is evident from Table 6. Difference between test and control totals amounts to 104.7%. Since

TABLE 3

LESIONS PRODUCED IN DUGESIA TIGRINA BY HEXENOLACTONE AND THE COMBINED EFFECT OF HEXENOLACTONE AND D-ISOLEUCINE

H=Hexenolactone
HI=Hexenolactone plus d-isoleucine

Series, Molarity in n x 10^{-5}M	No. of exp.	Number of worms	Hours	Total lesion area in $mm^2/100$ H	HI	% Diff.
		40	17	1384	1596	−15.4
I		40	16	957	837	+14.4
H n=5	5	40	16	798	713	+11.8
I n=5		40	18	2374	2947	−24.1
		40	19	2809	2779	+ 1.1
		40	17	1746	1714	+ 1.9
II		40	17	777	1177	−51.5
H n=5	5	40	18	1217	1233	− 1.3
I n=2		40	19	907	1341	−47.9
		40	19	1586	1498	+ 5.9

TABLE 4

LESIONS PRODUCED IN DUGESIA TIGRINA BY HEXENOLACTONE AND THE COMBINED EFFECT OF HEXENOLACTONE AND GLYCINE

H=Hexenolactone
HG=Hexenolactone plus Glycine

Series, Molarity in n x 10^{-5}M	No. of exp.	Number of worms	Hours	Total lesion area in $mm^2/100$ H	HG	% Diff.
		40	15	371	491	−32.4
I		40	16	805	991	−23.1
H n=5	5	40	16	1382	1393	− 0.8
G n=2.5		40	16	720	945	−31.2
		40	18	790	1270	−60.7
		40	16	813	1474	−81.3
II		40	17	805	1243	−54.4
H n=5	5	40	17	854	1070	−25.3
G n=1		40	18	2043	1903	+ 7.4
		40	18	1576	1758	−11.5

the experimental medium contained only one molecule of cysteine for every two molecules of hexenolactone, and the two compounds are known to react with one another (fig. 7), the difference of approximately 100% between test and control is especially interesting.

Cysteine at a concentration of 25×10^{-5}M completely prevents lesion in test animals up to about 30 hours of exposure. When measured at 46 hours the test animals had triclad lesions, still considerably

TABLE 5

LESIONS PRODUCED IN DUGESIA TIGRINA BY HEXENOLACTONE AND THE COMBINED EFFECT OF HEXENOLACTONE AND D-GLUTAMIC ACID

H=Hexenolactone
HGlu=Hexenolactone plus d-Glutamic Acid

Series, Molarity in n x 10^{-5}M pH	No. of exp.	Number of worms	Hours	Total lesion area in $mm^2/100$ H	HGlu	% Diff.
I						
H n=5		40	17	851	1147	−34.5
pH 6.6	3	40	18	336	1085	−222.9
Glu n=2		40	18	1136	1497	−31.7
pH 6.3						
II						
H n=5		40	16	269	277	− 2.9
pH 6.6	3	40	17	225	391	−73.8
Glu n=2		40	18	235	298	−26.8
pH 6.6						

TABLE 6

EFFECT OF THE ADDITION OF CYSTEINE TO HEXENOLACTONE MEDIUM

Lesion areas expressed in $mm^2/100$ measured after 18 hours of exposure and arranged in order of magnitude of percent difference between individuals in each of 18 matched pairs. pH in both solutions was 7.05.

Hexenolactone 5 x 10^{-5}M	Cysteine 2.5 x 10^{-5}M plus Hexenol. 5 x 10^{-5}M	% Difference
194	21	+824
173	29	+496
169	38	+344
103	25	+312
156	52	+200
219	78	+180
181	79	+129
82	37	+122
174	101	+ 72
166	98	+ 69
64	40	+ 60
106	64	+ 56
143	96	+ 49
44	30	+ 43
107	82	+ 30
47	38	+ 23
72	69	+ 4
157	178	− 11
Totals 2357	1155	Difference between totals 104.7%

smaller than control injury at 20 hours (Table 7). The chemical interaction between hexenolactone and cysteine (Hauschka et al., 1945, see fig. 7) was shown to be such that disulfide gradually in-

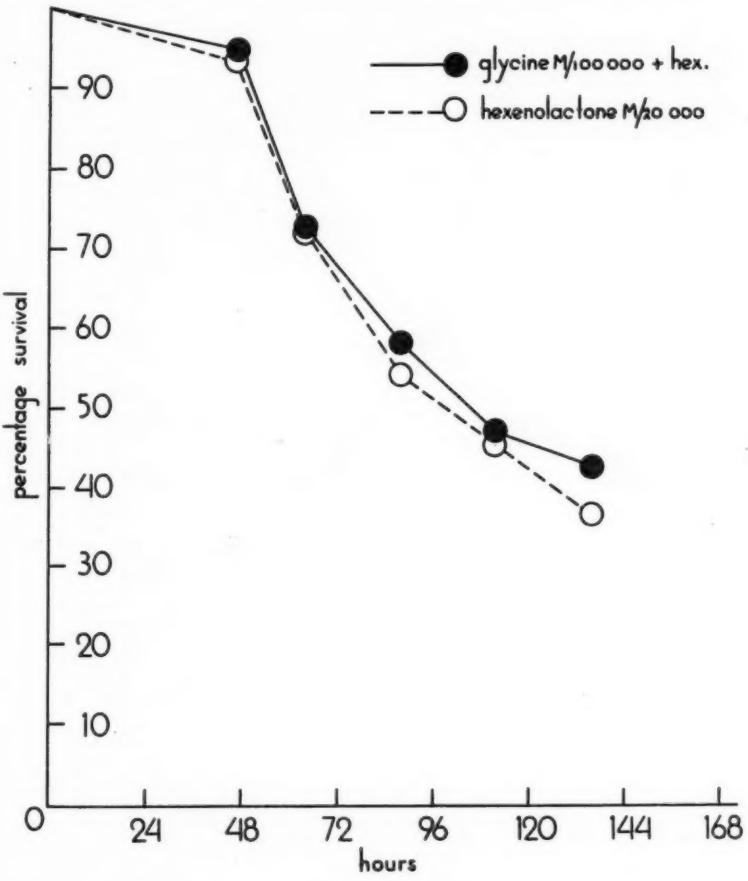

FIGURE 5

ABSENCE OF GLYCINE EFFECT (1×10^{-5}M) ON SURVIVAL OF DUGESIA TIGRINA IN HEXENOLACTONE MEDIUM

This graphic representation is based on 100 test animals and 100 controls.

creased while the combined SH decreased, and the spectrophotometric analysis for hexenolactone increased after an initial decrease. These findings are substantiated by the biological results.

The effect of cysteine on survival of *Dugesia* in lactone media is

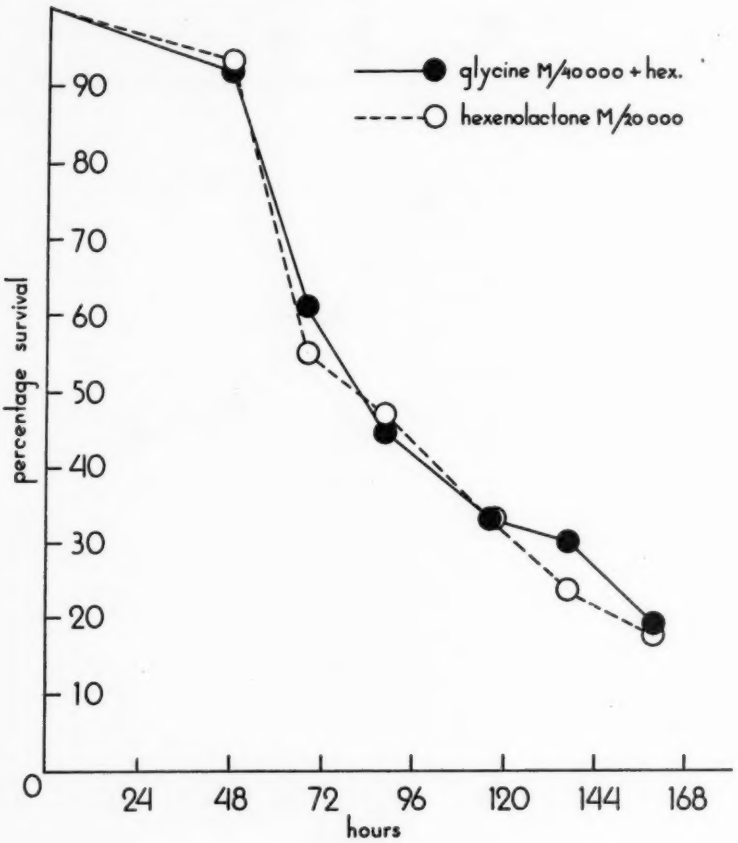

FIGURE 6

ABSENCE OF GLYCINE EFFECT (2.5 x 10^{-5}M) ON SURVIVAL OF DUGESIA TIGRINA IN HEXENOLACTONE MEDIUM

This graphic representation is based on 100 test animals and 100 controls.

TABLE 7

LESIONS PRODUCED IN DUGESIA TIGRINA BY HEXENOLACTONE AND THE COMBINED EFFECT OF HEXENOLACTONE AND CYSTEINE

Injury to the controls at 46 hours was too far advanced for measuring. These data are in keeping with the reversible reaction between SH and hexenolactone pictured in fig. 7.

H=Hexenolactone
HCt=Hexenolactone + cysteine

Molarity in n x 10^{-5}M	No. of exp.	Number of matched worms	Hours	Total lesion area in $mm^2/100$ H	HCt
H n=5		20	20	1205	0
			46	—	450
	3	20	20	1092	0
Ct n=25			46	—	545
		20	20	884	0
			46	—	249

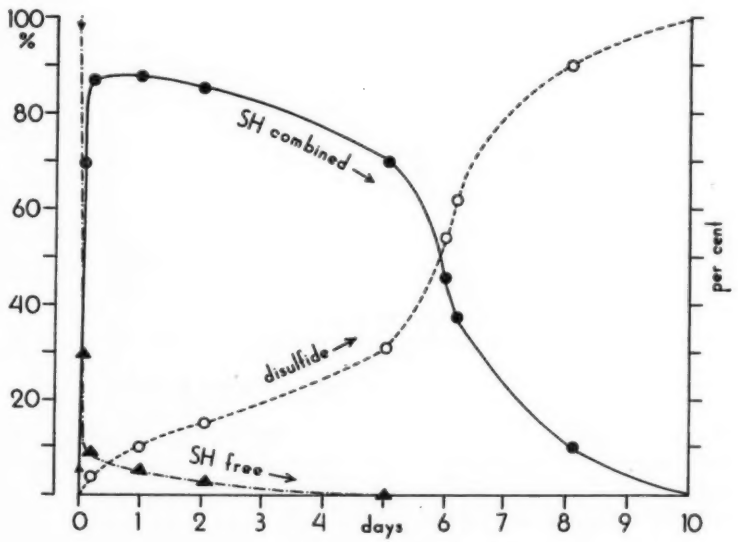

FIGURE 7

INTERACTION BETWEEN HEXENOLACTONE (1 x 10^{-2}M) AND EQUIMOLAR CYSTEINE UNDER RELATIVELY ANAEROBIC CONDITIONS

For details on this reaction refer to Hauschka, Toennies and Swain, 1945.

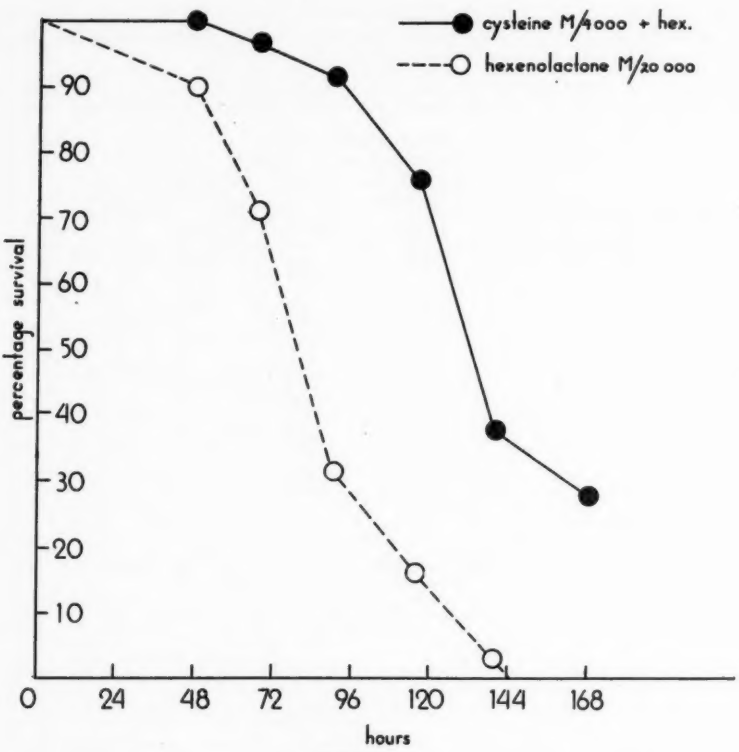

FIGURE 8

EFFECT OF CYSTEINE (25×10^{-5}M) ON SURVIVAL OF DUGESIA TIGRINA IN HEXENOLACTONE (5×10^{-5}M)

This graph is based on the 60 animals represented in Table 7.

plotted in fig. 8. Comparison between figs. 8 and 9 demonstrates convincingly the importance of the SH group in the protective role of cysteine. The animals plotted in fig. 9 were kept in constantly aerated media (which were not renewed daily, as in all the other experiments). Aeration, in the latter experiment rapidly oxidized cysteine to cystine which was not effective. This conclusion is borne out also by 5 separate experiments with 2 concentrations of cystine, summarized in Table 9.

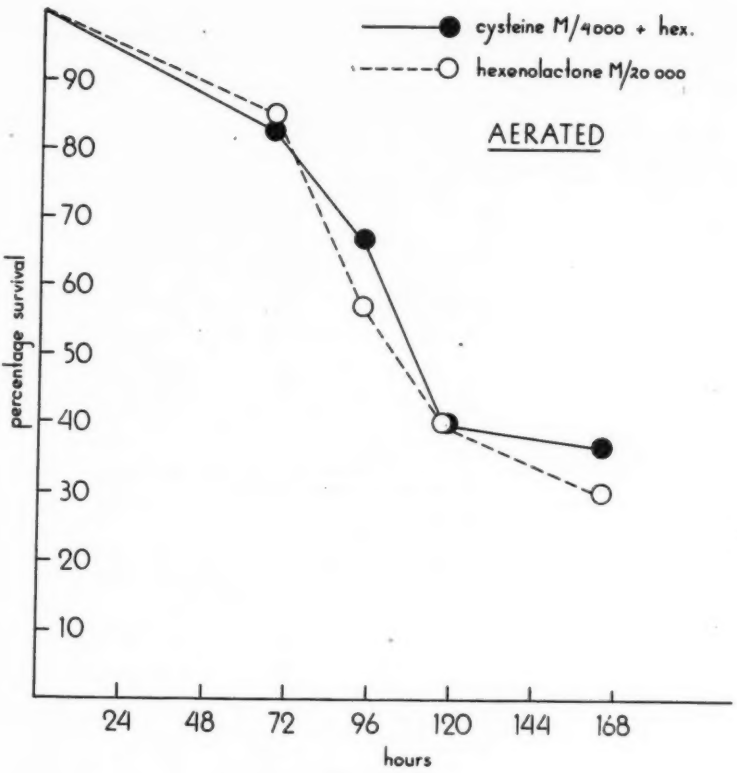

FIGURE 9

ABSENCE OF EFFECT OF CYSTEINE (25×10^{-5}M) ON SURVIVAL OF DUGESIA TIGRINA IN 5×10^{-5}M HEXENOLACTONE UNDER CONSTANT AERATION

Aeration oxidizes cysteine to cystine which does not counteract hexenolactone. This graph comprises 40 individuals.

The tripeptide glutathione, consisting of the amino acids glycine, glutamic acid, and cysteine, also produced partial inactivation of hexenolactone (Table 8). As neither glycine nor glutamic acid or cystine counteract the lactone, the effect was again through sulfhydryl. The influence of feeding on survival in glutathione media is shown in fig. 10.

TABLE 8

LESIONS PRODUCED IN DUGESIA TIGRINA BY HEXENOLACTONE AND THE COMBINED EFFECT OF HEXENOLACTONE AND GLUTATHIONE

H=Hexenolactone
HGt=Hexenolactone plus Glutathione

Series, Molarity in n x 10^{-5}M	No. of exp.	Number of worms	Hours	Total lesion area in $mm^2/100$ H	HGt	% Diff.
I		40	17	1374	826	+66.3
H n=5	3	40	17	665	401	+65.8
Gt n=2		40	18	1597	1039	+53.7
II						
H n=5	2	40	14	997	583	+71.0
Gt n=5		40	14	930	765	+21.6
III						
H n=5	2	20	17	807	293	+172.0
Gt n=25		20	17	496	168	+195.3

TABLE 9

LESIONS PRODUCED IN DUGESIA TIGRINA BY HEXENOLACTONE AND THE COMBINED EFFECT OF HEXENOLACTONE AND CYSTINE

H=Hexenolactone
HC=Hexenolactone plus Cystine

Series, Molarity in n x 10^{-5}M	No. of exp.	Number of worms	Hours	Total lesion area in $mm^2/100$ H	HC	% Diff.
I		20	18	795	832	− 4.7
H n=5	3	20	18	798	754	+ 5.5
C n=12.5		20	18	736	776	− 5.4
II						
H n=5	2	20	19	688	912	−32.6
C n=2.5		20	19	719	840	−16.8

In Part I of this paper, temporary overgrowth of wounds by thickened sheaths of epithelium was discussed from the viewpoint of tissue-differential damage. The "repair period" extended from the third to the sixth day of exposure to 5 x 10^{-5}M hexenolactone. Not more than 5% of the animals "healed" in the control media. In the presence of glutathione, however, complete repair of wounds amounted to 22%. In fig. 11, based on 1840 animals, percentage of "healing" in the various test and control media is graphically arranged in order of magnitude, and significant positive deviation of the glutathione value from its control is evident. The only other possibly significant value

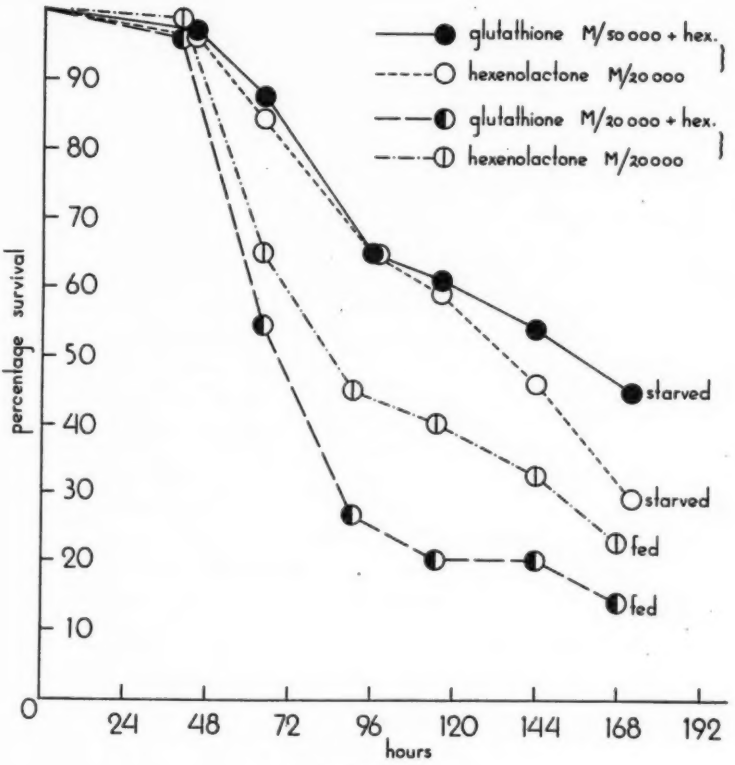

FIGURE 10

ABSENCE OF GLUTATHIONE EFFECT ON SURVIVAL OF DUGESIA TIGRINA IN HEXENOLACTONE MEDIA. POSITIVE EFFECT OF STARVATION ON SURVIVAL

The four curves represent a total of 200 animals.

in this graph is that for 2.5×10^{-5}M beta-alanine. These results are in keeping with hexenolactone activity data summarized in Table 1.

7. In order to gain some insight into the failure of hexenolactone to affect the growth of pathogens in the mammalian body—in contrast to very effective inhibition in vitro (Hauschka, Maxwell and Johnson, 1945)—40 specimens of *Dugesia tigrina* were exposed to a medium containing 0.8 cc. of fresh human serum per 100 cc. of 3×10^{-5}M

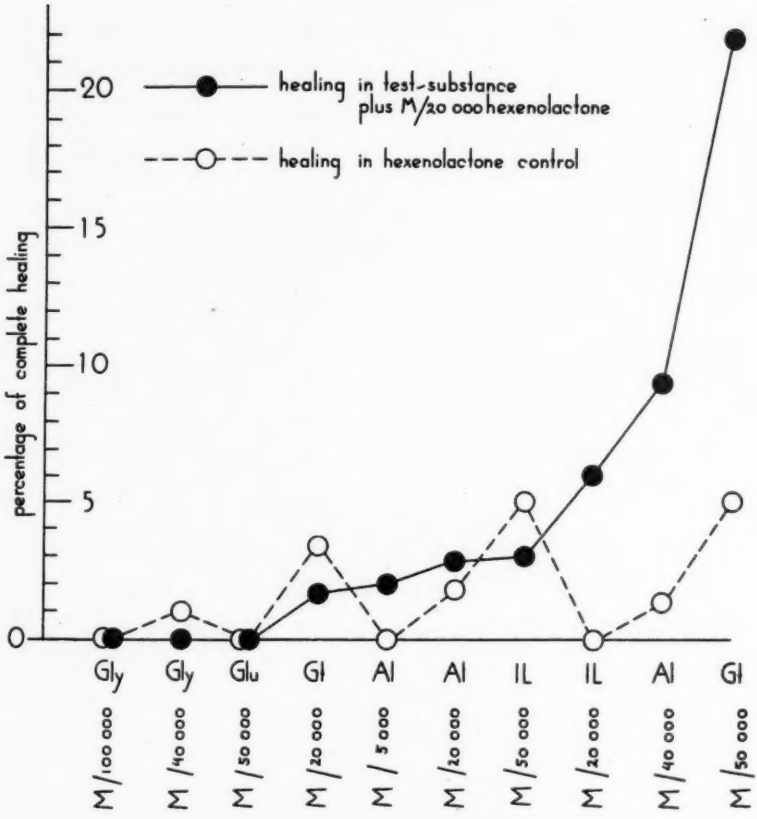

FIGURE 11

COMPLETE REPAIR OF LESIONS IN THE PRESENCE OF VARIOUS TEST-SUBSTANCES ADDED TO 5 x 10^{-5}M HEXENOLACTONE. MARKED GLUTATHIONE EFFECT

This graph represents, in order of magnitude, the percentage of complete healing in 1840 treated flatworms half of which served as hexenolactone controls. Control repair varies from 0 to 5%. The value for 2 x 10^{-5}M glutathione (21.5%) is significant. Other test-substances include glycine (Gly) at two concentrations, glutamic acid (Glu), beta-alanine (Al) at three concentrations, and iso-leucine (IL) at two concentrations.

hexenolactone. Control solution contained an equivalent amount of physiological saline. Lesions in the serum-lactone combination were without exception consistently smaller than control lesions, with a total of 2379 mm.^{2}/100 for the test, and 3242 for the control. Presumably the lactone interacted with SH groups and other components of the serum proteins.

Discussion

In a study of the nutritive requirements of growing cells, Heaton (1926, 1929) discovered a factor in malt and in yeast grown on malt which had marked inhibitory effects on amphibian metamorphosis, regeneration, fibroblasts, Jensen rat-sarcoma, and the growth of young mammals. Medawar (1937), also working with malt extracts, isolated a factor which he characterized as a "differential mesoderm inhibitor". At a mesenchyme-inhibiting concentration this substance did "not retard the growth of those tissues, irrespective of their embryonic origin, which behave in vitro as epithelia". Medawar's qualified designation should therefore be interpreted in terms of tissue-culture rather than ontogeny.

The synthesis of delta-hexenolactone by Medawar and the Robinsons (1943), and independently by Kuhn and Jerchel (1943), and the demonstration of structural identity with the natural lactone from Sorbus berries, have facilitated a number of studies devoted specifically to the tissue-differential effects of this compound. The inhibitor was found to suppress the germination of seeds and pollen as well as the growth of certain micro-organisms and animal tissues.

Some bacteria, e.g. lactic acid bacteria and *Strepto-bacterium plantarum,* and some animal epithelia, e.g. chick epithelia and Ehrlich carcinoma, are relatively unresponsive. Other micro-organisms, such as *Staphylococcus aureus,* resemble fibroblasts and mesenchymal cells in their great sensitivity to the inhibitor (Kuhn, Jerchel, et al., 1943).

Royle (1945) found no clear-cut differential effects of hexenolactone on fibroblasts and epithelial cells in vitro.

In an analysis of hexenolactone effects on frog embryos, Briggs (1945) found the vegetal portion of the blastula (future endoderm) particularly sensitive. In gastrulae and neurulae the endoderm and medullary plate were more "disorganized" than other tissues. Heart and gills were especially sensitive during later development, but other

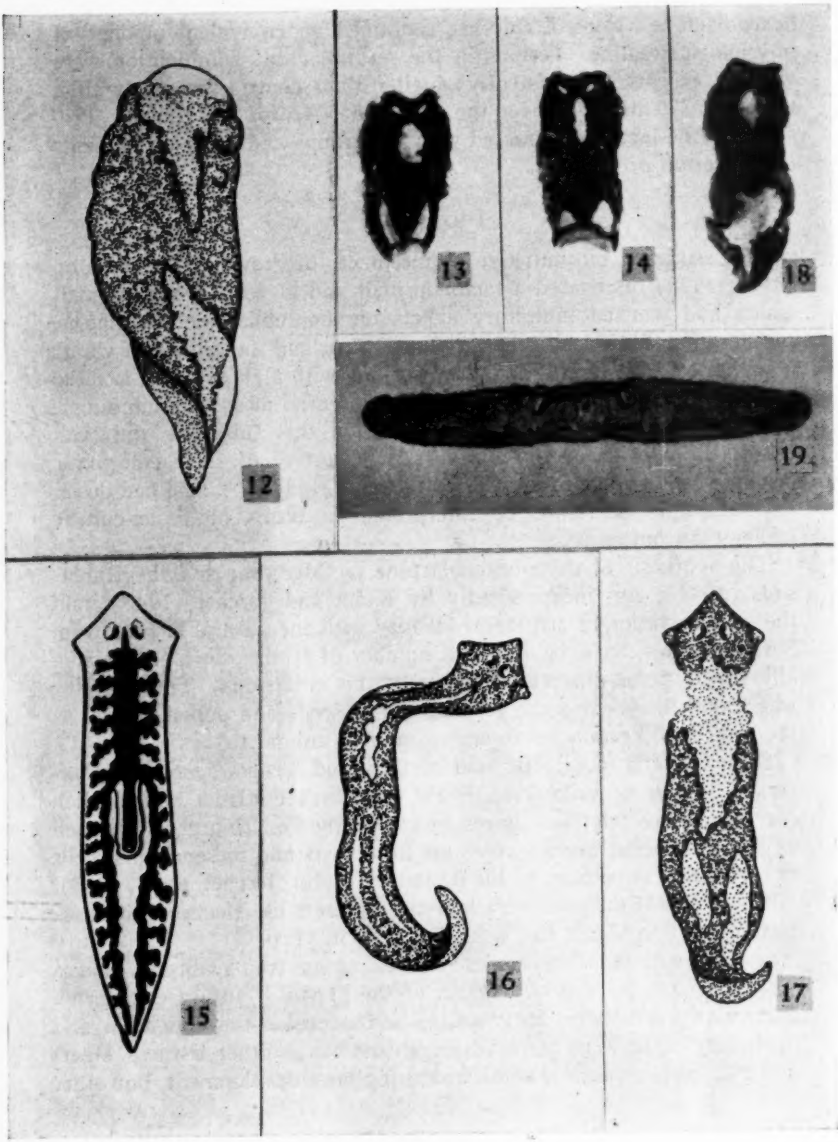

PLATE I

FIGURE 12

Effect of hexenolactone on head regeneration. No head cone has developed. Epidermis has grown over wound areas without supporting mesenchyme. Lesions have appeared in the dorsal body wall above the gut.

FIGURES 13, 14

Triclad lesion pattern induced in Dugesia tigrina by 5×10^{-5}M hexenolactone, photographed in living specimens.

FIGURE 15

Diagram showing the three main branches of the planarian intestine with diverticula and proboscis.

FIGURE 16

Rigid "swan-like" pose maintained by most animals after the three lesions have developed.

FIGURE 17

Disintegration of mid-body leading to loss of head which continues to live longer than rest of flatworm.

FIGURE 18

Photograph of living specimen. The two posterior lesions have increased in size and merged into one wound area. The head is flexed upward as in Fig. 16.

FIGURE 19

Photograph of cross-section through the eye region of a planarian after 6 days in 5×10^{-5}M hexenolactone. No damage to the tissues of the head is noticeable. The same animal showed extensive injury of gut and surrounding tissues.

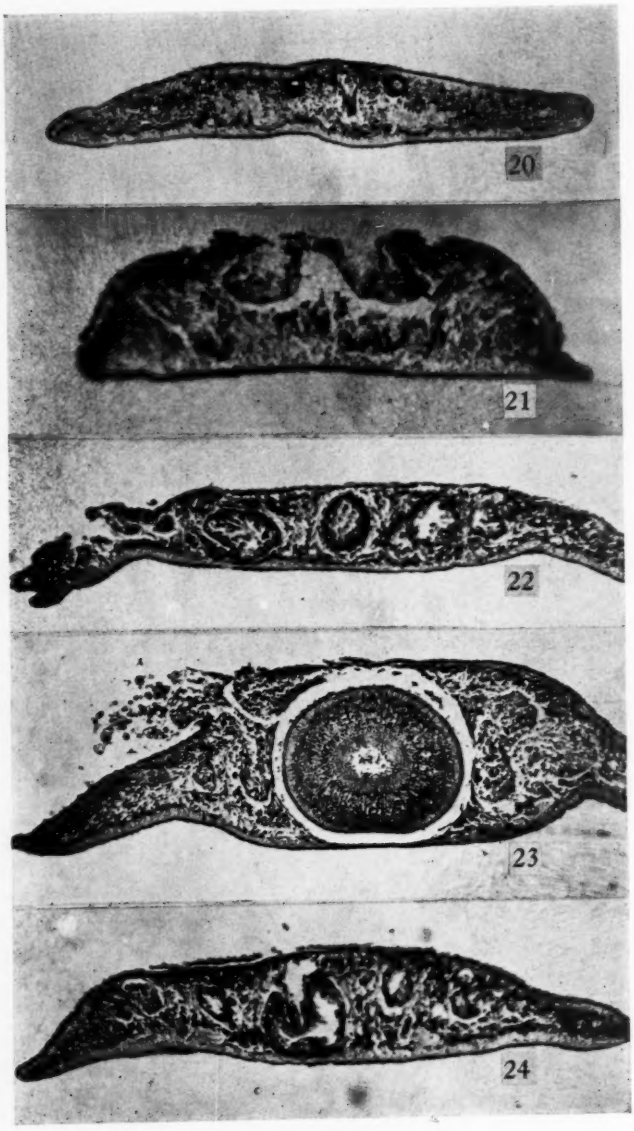

PLATE II

FIGURE 20

Transverse section through eye region of normal worm.

FIGURE 21

Transverse section through fore-gut of hexenolactone-treated worm. The dorsal body wall above the gut has disintegrated. The intestine is disconnected from the surrounding parenchyma.

FIGURE 22

Section through anterior portion of proboscis and the two posterior intestinal branches of an untreated worm. The left margin was damaged during fixation.

FIGURE 23

Section through proboscis and the two posterior branches of the intestine of an animal treated with hexenolactone. A lesion has developed above the left intestinal branch. The right branch has no clearcut lumen and appears partly disintegrated and separated from the mesenchyme.

FIGURE 24

Section through anterior gut and diverticula of control animal.

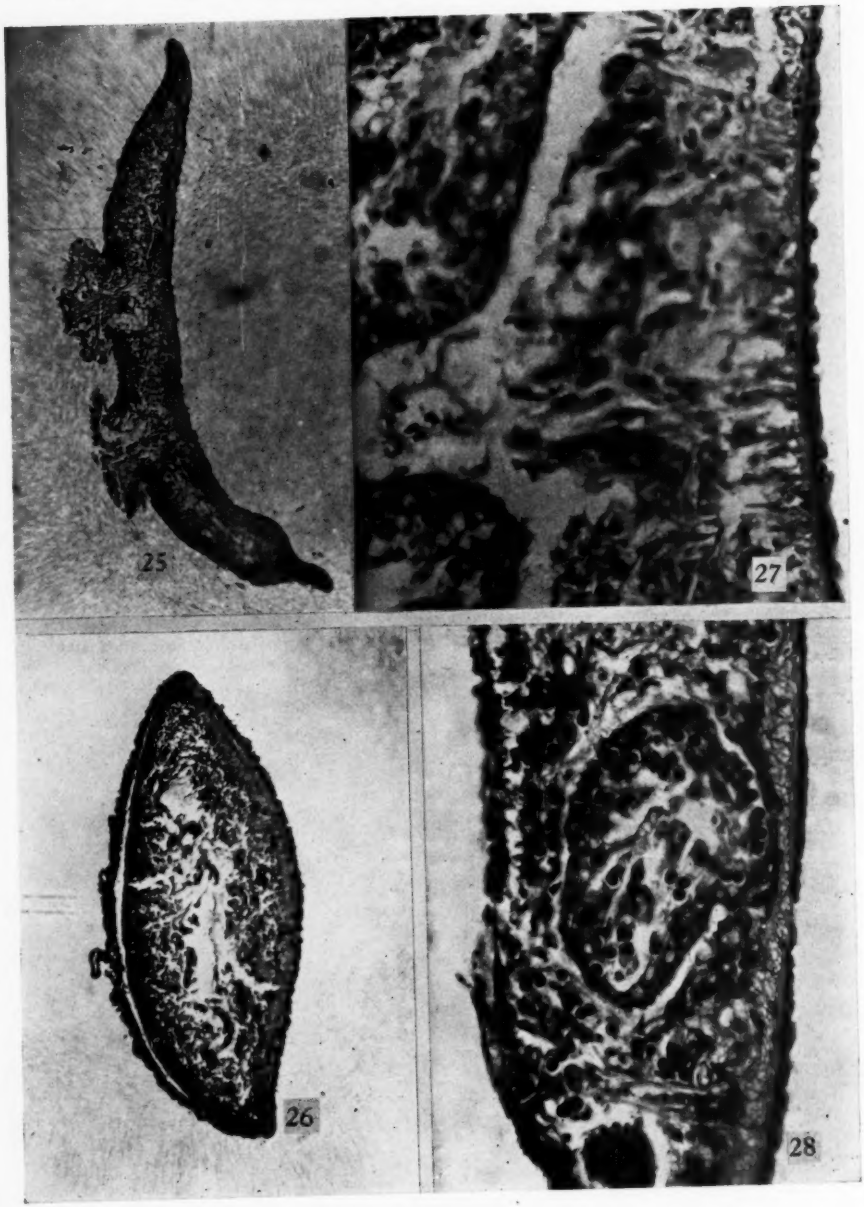

PLATE III

FIGURE 25

Transverse section through posterior body region of hexenolactone-treated worm. The intestinal tissues and surrounding mesenchyme and muscle are sloughed off through the two dorsal lesions.

FIGURE 26

Cross-section through anterior gut of a planarian in which the dorsal lesions have "healed over" (in the presence of 5×10^{-5}M hexenolactone). The new growth of epidermis is two cell layers thick, shows papillomatous protuberances and is not in contact with underlying mesenchyme. Note loss of gut and disorganized appearance of parenchyma.

FIGURE 27

Part of the section pictured in Fig. 21 at higher magnification. Ventral epidermis (on right) appears normal, gut and mesenchyme look necrotic.

FIGURE 28

Enlarged part of control section pictured in Fig. 22 showing normal appearance and distribution of tissues.

mesodermal tissues were not. Ectodermal organs, with exception of the central nervous system and eyes, were very little affected. On the whole the experiments of Briggs demonstrate no striking differential effect on any one class of germ-layer derivatives.

The findings for *Dugesia tigrina* discussed in Part I of this paper clearly reveal a tissue-differential susceptibility, with epidermis least and intestinal tissues probably most affected. It should be emphasized, however, that these studies concern the response of adult tissue, not the inhibition of actively growing and dividing cells in embryos or tissue-culture.

As to the chemical mechanism of growth inhibition and tissue injury by hexenolactone, the following possibilities suggested themselves: interference with pantothenic acid metabolism (Medawar et al., 1943); activity through an undetermined mechanism involving alanine (Hauschka, 1944); damage to cells caused by peroxide, as in the case of the angelicalactones (Mendez, 1944); a direct and reversible interaction between R-SH and hexenolactone. The latter was demonstrated by Hauschka et al (1945) through colorimetric and spectrophotometric studies, as well as through bio-assay.

Since no peroxide was detected by the most sensitive procedures in any of our test media or stock solutions, the inactivation of hexenolactone by sulhydryl compounds cannot be explained through blocking of metal catalysis or a reaction between sulfhydryl and peroxide. Furthermore, the inorganic and organic peroxide to which *Dugesia* was exposed did not produce the triclad lesion pattern typical for hexenolactone, but caused "axially graded" disintegration, beginning with the head. Tests in which serum was added to hexenolactone media indicate that the lactone may also combine with protein-SH groups. Hence, inhibition or injury of cells could be accomplished through a large number of enzymes which require sulfhydryl in the activating protein (dehydrogenase) portion of the enzyme complex (Barron and Singer, 1945; and Singer and Barron, 1945). The important role of sulfhydryl, not only in cell-maintenance but also in cell-division (Hammett, 1929) and morphogenesis (Brachet, 1938), is borne out indirectly by the demonstrated interaction between the naturally-occurring growth inhibitor hexenolactone and sulfhydryl groups. Inactivation by SH of the antibiotic properties of penicillin and several widely different bacteriostatic substances (Cavallito and

Bailey, 1944) also belongs in the category of indirect evidence for the fundamental function of SH in growth.

Direct reaction with sulfhydryl may not be the only channel through which hexenolactone affects living tissues. Counteraction of the inhibitor by both alpha- and beta-alanine, but not by pantothenic acid (Hauschka, 1944), eliminates the possible function of the latter in the inhibitory reaction-chain. Smythe (personal communication) advanced the theoretically interesting possibility that pyruvic acid might affect the action of hexenolactone. Conceivably, pyruvic acid could be an intermediate common to cysteine, alpha-alanine and beta-alanine.

Another path through which alanine might act is a reaction described by Fromageot and co-workers (as discussed by Smythe, 1944) taking place in dog liver, and catalyzed by the hypothetical enzyme "desulfurase":

$$3\ \text{Cysteine} \rightleftharpoons \text{Cystine} + H_2S + \text{Alanine}$$

Excess alanine could thus protect cysteine and thereby indirectly lessen the activity of hexenolactone.

On the other hand, beta-alanine in a concentration of 20×10^{-5}M does not inactivate 5×10^{-5}M hexenolactone, while equimolar concentrations of beta-alanine have a consistent and significant antagonistic effect. Perhaps the higher concentrations of beta-alanine enable certain beta-alanine derivatives to counteract the effective amounts of alanine. According to Nielsen and Johansen (1943) the stimulating effect of beta-alanine on yeast growth is almost completely counteracted by beta-aminobutyric acid, and to a lesser extent by other derivatives.

Our results showed cysteine SH to be more effective as an antagonist of hexenolactone than glutathione SH. Apart from the greater stability of the latter, it is conceivable that cysteine (thio-alanine) performs a double function through its sulfhydryl group and through its alanine-like molecular configuration.

One of the most striking features of flatworm disintegration under the influence of hexenolactone was its variance from the classical antero-posterior gradient syndrome.

The non-specificity of axially graded response to a wide variety of chemical and physical agents which have "nothing in common ex-

cept the property of causing cytolysis" (Buchanan and Levengood, 1939) has been repeatedly emphasized by Child (1941). Together with respiratory gradation along the main body axis, differential susceptibility is held as expressive of a single dynamic metabolic gradient varying in intensity and operating as a factor in development.

Although the existence of physiological gradients as indicators—rather than determinants—of developmental activity is undeniable (see criticisms by Parker, 1929; Weiss, 1939; and Lindahl, 1942), the susceptibility method for demonstrating such gradients is of questionable value. Wilson (1931) convincingly attributes the "nonspecific" axially graded response of flatworms to KCN and other toxic agents to the reaction of the marginal slime-producing cells. Prolonged action of any agent that stimulates these cells to secretion "would lead to a failure of normal secretion and to premature swelling of the granules in the margin," and subsequent rupture of the margin. The rupture occurs first at the angles of the margins in the head region, "because the swelling is here restricted in more dimensions than along the sides"; hence disintegration from the head caudad and from the margins inward.

Splitting of the lateral margins is such that "superficial dorsal and ventral plates may be lifted off the body" and is entirely distinct from the triclad lesion pattern induced by hexenolactone.

The apparent specificity of the lactone effect (produced by none of 18 other toxic substances tested) serves to emphasize the unreliability of a nonspecific susceptibility pattern as evidence for qualitative identity of quantitatively graded metabolic activity along the body axis.

Hexenolactone damages flatworm tissues differentially, producing lesions which coincide with the pattern of the injured gut, whence damage radiates caudad, cephalad and in lateral direction. Epidermis, particularly in the head region, is least affected and is even capable of a limited amount of repair growth in 5×10^{-5}M hexenolactone. Concerning other tissues it is difficult to decide whether digestive cells are more susceptible than parenchyma cells. The latter, according to Murray (1927, 1931) are "the most adaptable type of planarian cell, with highest capacity for acclimatization, for they survive as much as two weeks after the more specialized types of cell, such as muscle, flame cell and digestive cell, have died."

The hexenolactone lesions were particularly severe in well fed specimens of *Dugesia tigrina*. Child (1941, page 737) recognizes the susceptibility differences produced by differences in physiological condition between the actively functioning and the long-starved gut. He observes that in "well fed animals the gut disintegrates as early as, or even earlier than the body wall; but after long starvation, later than the body wall." Lund (1938), on the other hand, quotes Child as stating that young and starved planarians show a greater degree of susceptibility to KCN than the older worms and the well fed worms respectively.

Parker (1929) exposed *Nereis virens* to KCN and found that the head and tail disintegrated before the mid-trunk regions did. But instead of interpreting this result as expressive of a metabolic gradient he considered it the consequence of differential penetration. "The cyanide enters the worm more effectively at the mouth and at the anus than it does in the mid-trunk and thus the ends die and disintegrate before the middle of the worm does."

The hexenolactone-induced lesion pattern in *Dugesia tigrina* may, therefore, be explained both on the basis of differential penetration and tissue-differential susceptibility, possibly conditioned by differential distribution of enzyme complexes requiring reduced SH for their proper functioning.

Summary

1. The tissue-differential response of the flatworm *Dugesia tigrina* to hexenolactone (parasorbic acid) was established on the basis of triclad lesions coinciding with the three branches of the gut and from histology and cytology of sectioned material. Intestinal epithelium and mesenchyme were found considerably more susceptible than epidermis.

2. Heads generally remained intact and survived longer than the mid- and hind-body. This sequence of disintegration is the exact opposite of Child's axially graded susceptibility pattern.

3. The hexenolactone effect was specific and could not be produced by a variety of other toxic compounds.

4. Lesion size after 16-20 hours of exposure to 5×10^{-5}M hexenolactone was relatively constant and was a reliable quantitative criterion of lactone activity.

5. Well fed worms exhibited more severe damage than starved animals.

6. Hexenolactone did not injure tissues through peroxide (as appears to be the case with the angelicalactones). No peroxide was found in hexenolactone media and the triclad lesion pattern was not evoked by inorganic or organic peroxide in various concentrations.

7. Hexenolactone was partly inactivated by alanine and sulfhydryl. Equimolar cystine and iso-leucine had no effect on lactone activity which seemed to be slightly increased by the presence of glycine and glutamic acid.

8. Biochemical aspects of tissue damage by hexenolactone are discussed from the point of view of inhibitory mechanism.

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